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PESTICIDES IN PEOPLE

DDT and DDE in the Blood and Diet of Eskimo Children from Hooper Bay, Alaska[1]

William F. Serat, Min K. Lee, Albert J. Van Loon, Donald C. Mengle, James Ferguson,[2] John M. Burks,[3] and Thomas R. Bender[4]

ABSTRACT

An analysis of the levels of DDT and DDE in the blood of some Alaskan Eskimo children and in the fat of some local marine mammals taken for food suggests that the children's pesticide burden is only modestly lower than that of other American children. Authors suggest that some other food source, perhaps packaged food, supplies a portion of the dietary chlorohydrocarbon pesticide.

Introduction

Marine mammals from virtually all waters contain chlorinated hydrocarbon contaminants in their tissues, reflecting the ubiquitous distribution of agricultural and industrial chemicals (*2,3,7,8,15*). Highest levels of DDT have been reported in migratory seals from Canadian waters of the North Atlantic, from the North Sea, and from the Baltic Sea (*8*). Except for nonmigratory harbor seals (*1*), the pesticide and its metabolites are generally less prominent in the tissues of mammals from Antarctic and Pacific waters.

Although perhaps less dependent on aquatic food sources now than in the past, native populations of western coastal Alaska still derive a substantial portion of their diet from the sea. Thus in the absence of any other substantial contact with DDT, levels of the pesticide and its metabolites in tissues of Alaskan Natives likely reflect the marine component of their diet.

Children and adolescents in these Eskimo populations have lived in the era of worldwide contamination by chlorohydrocarbons. Although a portion of any body burden of DDT-type materials may well have been received through the placenta or from breast milk (*4,5,10*), such sources would be difficult to evaluate in the presence of a contaminated marine diet for all but the very young. This paper reports results of a study undertaken to determine whether blood levels of DDT and DDE in Eskimo children of western Alaska are near those of children from other segments of the American population. Alaskan seals and waterfowl which are used as food were also examined for chlorohydrocarbons.

Methods

BLOOD SAMPLES

In May 1972, serum and heparinized whole blood were collected from 40 Eskimo children in Hooper Bay. Thirty-eight sera with 25 matching whole blood samples, and two single whole blood samples were available. They were selected from a listing of 204 specimens which had been collected for other purposes. This list representing nearly every school child in the village, kindergarten through ninth grade, was stratified by grade level and sex. A technique of substitution was used so that no specimens finally selected were from children in the same household. The donors' ages ranged from 6 to 17 years; there were 20 males and 20 females.

Aliquots of 2.0 ml whole blood or sera were extracted with 6.0 ml hexane on a slow rotary mixer. Nanograde (Mallinkrodt) hexane was used in the extraction and as a rinse for all glassware.

Pesticide residues in the extracts were quantitated by gas chromatography using electron-capture detectors. Two 6-ft-by-1/4-in. pyrex glass columns allowed separation of residues. One contained 1.5 percent OV-17/1.95 percent QF-1 on 100/120 mesh Chromosorb WHP, and the other

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contained 5 percent OV-210 on 80/100 mesh Supelcoport. Columns were maintained at 190° C, inlets at 215° C, and detectors at 210° C. Detectors were operated in the pulsed mode, with 10 percent methane in argon carrier gas at 80 ml/min.

Pesticide residue standards were more than 99 percent pure. Recoveries of residues undergoing the analytical regimen were greater than 90 percent and the reliable sensitivity of detection was 0.001 ppm for *p,p'*-DDE and 0.002 ppm for *p,p'*-DDT. Measured residue levels in blood and food source samples were not corrected for recovery values.

FOOD SOURCE SAMPLES

In May 1974, animals which residents had hunted and killed for food near Hooper Bay were tested. Single samples of seal meat, seal fat, and sea duck meat, all components of the native diet, were cleaned by a modification of the procedure of Stanley and Le Favoure (*12*). Following digestion in a mixture of perchloric-acetic acids and extraction with hexane, fats in the extracts were destroyed in large part by treatment with 0.5 ml concentrated H_2SO_4 in a graduated centrifuge tube. After centrifugation, the DDT-DDE residues were quantified by procedures described above. The limit of sensitivity was 0.001 ppm DDE and 0.002 ppm DDT. Neither the digestion mixture nor the H_2SO_4 contained extractable interfering material.

In April 1975, five additional samples of seal oil from hunted species were obtained from food caches in villages 150 miles south of Hooper Bay. Following three extractions with 20 volumes of acetonitrile the extracts were chromatographed. Interfering peaks appeared, so the acetonitrile extracts were mixed with six volumes of water and then extracted with hexane. Acceptable quantitation of chlorohydrocarbons could be made from the hexane solution with minimal interference after reacting with concentrated H_2SO_4. Chromatographic columns were similar to those used to quantitate residues extracted from blood. One column was prepared with 5 percent OV-210 on 100/120 mesh Gas-Chrom Q and the other with 1.5 percent OV-17/1.95 percent QF-1 on 80/100 mesh Gas-Chrom Q. The former column operated at 183° C with the carrier gas at 95 ml/min and the latter operated at 200° C under a gas flow of 80 ml/min. Reliable sensitivities were 0.001 ppm for DDE and 0.002 ppm for DDT.

Polychlorinated biphenyl compounds (PCB's) are reported to be as ubiquitous as DDT-type materials. For this reason extraneous gas-chromatographic peaks in the extract of seal fat were compared with peaks obtained in chromatographing the PCB compound, Aroclor 1242. No correlation could be made between unidentified peaks from the seal fat extract and six prominent peaks from a chromatogram of the PCB. Therefore, authors cannot report the presence of any such contaminant in the fat sample at the sensitivity level of 0.2 ppm for nonmetabolized material by the methods used.

Aroclor 1254 chromatographed on 1.5 percent OV-17/1.95 percent QF-1 on Gas-Chrom Q presented one major peak, from a total of ten, which had a retention time of 6.4 minutes in contrast to 5.0 minutes for *p,p'*-DDE. Thus there is no discernible nonmetabolized PCB (Aroclor 1254) in lipids from the seals indigenous to the coast of western Alaska, determined at a sensitivity of 0.2 ppm.

Results

DDT-DDE

Table 1 summarizes results of analyses of DDE in serum. Pesticide levels in the whole blood samples were, in every case where matching serum levels were available for comparison, lower than serum levels by a factor which would relate to the dilution of serum by red blood cells. DDT levels in serum were beneath the limits of reliable detection (0.002 ppm) in 29 of the 38 samples and ranged from 0.002 to 0.003 ppm in the remaining nine sera.

TABLE 1. *Serum levels of* p,p'*-DDE in children of Hooper Bay, Alaska—1972*

Donor	Number	*p,p'*-DDE Levels, ppm	
		Mean	Range
Total	38	0.011	0.005-0.022
Male	19	0.011	0.005-0.022
Female	19	0.011	0.007-0.016
Ages 6-11 yr	18	0.011	0.005-0.018
Male	9	0.010	0.005-0.018
Female	9	0.012	0.009-0.016
Ages 12-17 yr	20	0.011	0.007-0.022
Male	10	0.012	0.008-0.022
Female	10	0.010	0.007-0.014

DDT-DDE IN FOOD-SOURCE SAMPLES

Pesticide levels in the single samples of seal fat, seal meat, and sea duck meat ranged from undetectable levels in seal meat to 0.110 ppm DDE and 0.020 ppm DDT in seal fat (Table 2). The highest residue in samples of seal oil was 0.80±0.01 ppm DDE (Table 3).

Discussion

A study reported in 1961 (*6*), preceding the present study by at least 11 years, indicated that DDT-related compounds were virtually absent in the natural dietary com-

TABLE 2. *Levels of* p,p'*-DDE and* p,p'*-DDT in three food source samples, Hooper Bay, Alaska—1974*

Sample	Pesticide Level, ppm				Percent Fat
	Weight Basis		Fat Basis		
	p,p'-DDE	*p,p'*-DDT	*p,p'*-DDE	*p,p'*-DDT	
Seal fat	0.105	0.019	0.110	0.020	95.5
Seal meat	ND	ND	ND	ND	0.4
Sea duck meat	0.004	ND	0.17	ND	2.4

NOTE: ND = no residues could be detected within limits of reliable sensitivity.

TABLE 3. *Levels of chlorohydrocarbon residues in seal oil, western Alaska—1975*

Collection Location	Residues, ppm		
	p,p'-DDE	*o,p'*-DDT	*p,p'*-DDT
Kuskokwim Bay near Kwigillingok			
(Spotted seal)	0.80±0.01	0.02±0.02	0.29±0.02
(Bearded seal, baby mukluk)	0.32±0.01	0.02±0.02	0.23±0.02
Kuskokwim Bay near Kongiganok	0.19±0.01	0.02±0.02	0.02±0.02
Kipnuk	0.36±0.01	0.02±0.02	0.13±0.02
Newtok	0.51±0.01	0.02±0.02	0.28±0.02

ponents of Alaska Natives. In addition the body fat levels of chlorohydrocarbons described for Natives were substantially lower than those of the general population. It might be assumed, on the basis of average values from a number of measurements, that *p,p'*-DDT levels in fat were some 450 times higher than in serum and that *p,p'*-DDE levels were some 400 times higher. Therefore, with reported mean levels of 0.8±0.10 ppm DDT and 2.0±0.41 ppm DDE in fat tissue, an approximate serum level of 0.002 ppm DDT and 0.005 ppm DDE might have been expected. Such estimated serum concentrations of the compounds for the study of 1961 (*6*) are similar to concentrations found now for the children and adolescents from Hooper Bay.

This comparison suggests that the body burden of these materials has remained relatively stable regardless of the route of exposure, and authors have no indication of recent local usage of any pesticide. Table 4 shows that chlorohydrocarbon levels in the serum of children of Hooper Bay are similar or only modestly lower than in children from most other areas (*9,11,13,14*). Children in South Carolina (*9*), especially black children, have demonstrated relatively high mean serum DDE and DDT levels, and reference adult populations had even higher levels.

The absence of chlorohydrocarbons in dietary samples reported in the previous Alaskan study (*6*) is in contrast to findings here, although differences in analytical techniques and corresponding sensitivities in measurements may well account for this.

TABLE 4. *Mean serum levels of chlorohydrocarbons in different populations of five States*

Reported Studies[1]	Age, yr	Chlorohydrocarbon, ppm	
		DDE	DDT
Hooper Bay, Alaska	6-17	0.011	<0.002
South Carolina (*9*)			
Whites	6-9	0.0246	0.0066
Blacks	6-9	0.0552	0.0185
Whites	Adults	0.0285	0.0112
Blacks	Adults	0.1222	0.0263
Florida (*11*)	—	0.0157	0.0042
Idaho (*14*)	3-10	0.0079	0.0021
	11-15	0.0130	0.0030
	16-20	0.0149	0.0030
Utah (*13*)	<21	0.0134	0.0036
	≥21	0.0209	0.0066

[1]Numbers in parentheses represent literature references cited in present study.

The levels of residues in seal fat, in seal oil, and in sea duck meat found in the present study are notably lower than those in fat of seals taken off eastern Scotland (5.5 ppm DDE and 7.8 ppm DDT), northern and western Scotland (3.4 and 3.8 ppm), and Cabot Strait (5.9 and 5.5 ppm) and Magdalene Island (1.2 ppm and 0.36 ppm) in the Gulf of Saint Lawrence, Canada (*8*). Furthermore, the levels found in this study do not approach those reported in fat samples of nonmigratory harbor seals from some regions of the eastern North Pacific Ocean (*1*). Geometric means of ΣDDT and PCB's were 611 ppm in seals from Puget Sound and 11 ppm in seals from Pribilof Islands. Data on the levels of DDE in various tissues from immature males and nursing pups of the northern fur seal from the Pribilof Islands or the coast of Washington (*2,3*) indicate that fat levels of the compound are seven times as high as those in liver. The immature males would thus be expected to contain some 5 ppm DDE in their fat, a value in keeping with those found in seals from North Atlantic waters.

If generally representative, the relatively low levels of chlorohydrocarbons found in the fat and oil samples reported here suggest that lower dietary exposures, at least from an indigenous meat supply, should prevail for Eskimos of western Alaska. This assumption is not borne out by levels of DDE and DDT in serum from the children of Hooper Bay. Environmental levels of the chemically stable compound, DDT, in that locale should not be affected by a recent moratorium on its use, since its introduction into the region would have been largely windborne and in notably smaller quantity than if it had been used in local agriculture. It is possible that prepackaged food available to many Alaska Natives, especially in school lunch programs, is a source of the chlorohydrocarbons in the children's blood. Modest dietary exposure and body burdens of the chlorohydrocarbons appear to have been maintained during the past decade or longer.

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RESIDUES IN FISH, WILDLIFE, AND ESTUARIES

Mercury, Arsenic, Lead, Cadmium, and Selenium Residues in Fish, 1971-73—National Pesticide Monitoring Program

David F. Walsh,[1] Bernard L. Berger,[2] and Jerry R. Bean[3]

ABSTRACT

As part of the National Pesticide Monitoring Program, the Fish and Wildlife Service, U.S. Department of Interior, analyzed selected fish samples from 100 monitoring stations for residues of mercury, arsenic, lead, cadmium, or selenium in 1971-73. At most stations, detectable residues of all metals were present in more than 95 percent of the composite samples. Fishes with mercury residues exceeding 0.5 mg/kg wet weight in the whole fish were mainly predators. Fishes with residues of arsenic, lead, cadmium, and selenium exceeding 0.5 mg/kg included predatory and nonpredatory species. The number of composite samples in which residues of these elements exceeded 0.5 mg/kg decreased from 1971 to 1973, whereas the percentage of samples with detectable residues increased slightly. Only selected samples were analyzed in 1973; therefore, these figures should be used only cautiously as trend data. Species of fish collected varied considerably between geographic regions but were similar from year to year within each region.

Introduction

The Fish and Wildlife Service (FWS) has contributed to the National Pesticide Monitoring Program by determining residues of various pollutants in fish. Authors have analyzed for organochlorines since 1967, mercury since 1969, and lead, cadmium, selenium, and the metaloid arsenic since 1971. Results of analyses were published for organochlorines through 1969 (*4,6*) and for mercury through 1970 (*5*). The present report presents results of analyses of heavy metals conducted on fishes collected 1971-73 at 100 stations throughout the United States (Fig. 1). On the basis of 1971 and 1972 results from 100 stations only, selected samples were analyzed for metals in 1973; caution should be exercised in interpreting these data. Except for Redhorse and fishes collected in Hawaii, common names of fishes used throughout this report are those designated by the American Fisheries Society (*1*). Redhorse is used to designate unidentified members of the genus *Moxostoma*. Fishes from the Hawaiian streams were Tilapia (*Tilapia mossambica*), Cuban limia (*Limia vittata*), and Chinese catfish (*Clarias fuscus*).

Methods

FISH COLLECTIONS

Fish were collected by FWS biologists, personnel of State fish and game agencies, and local commercial fishermen. Collection gear included a variety of nets and traps, hook and line, and electrofishing equipment. The use of chemical collecting agents was not permitted. As in previous reports (*1,7*) three composites of three species, each consisting of two to five adult fish, were to be collected at each of the stations from September to November. In the Hawaiian stations up to 26 fish were analyzed. Sample collections included a replicate for each species in 1971, but for only one of the three species from each station in 1972 and 1973. After length and weight of the fish had been determined, each composite was wrapped in foil, frozen, and shipped to the analytical laboratory for preparation and residue analyses. Localities of collection, species, size, and number of fish appear in Tables 1-3.

LABORATORY METHODS

1971—Two subsamples were taken from ground whole body composites: a 1-g sample for mercury and a 15-g sample for arsenic, cadmium, and lead. Mercury determinations followed the procedures of Okuno et al. (*13*).

Arsenic was measured by the Jarrell-Ash procedure (*7*) with the following modifications: a 1:1 (v/v) mixture of concentrated sulfuric acid (H_2SO_4) and nitric acid (HNO_3) was used to digest the 15-g samples, no perchloric acid was added during digestion, and the final volume was adjusted to 60 ml with distilled water. A subsample of the

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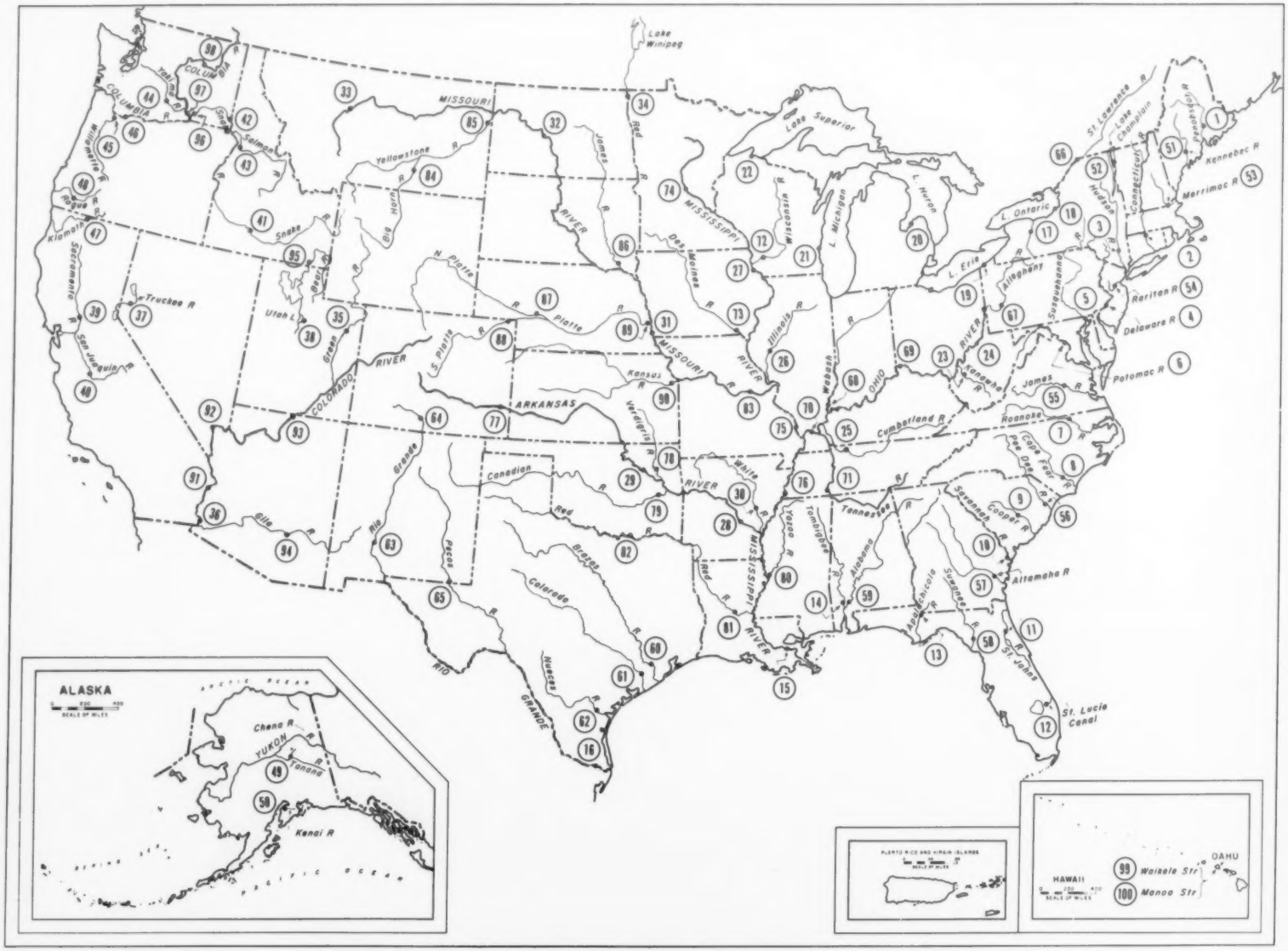

FIGURE 1. *Fish sampling stations, National Pesticide Monitoring Program, 1971-73*

digest representing 2.5 g of sample was analyzed by atomic absorption.

The digest from the arsenic procedure was also used for determining the presence of lead and cadmium. A subsample representing 10 g of sample was placed in a beaker and adjusted to 60 ml with distilled water, three drops of 1 percent (v/v) thymol blue were added, and the pH was adjusted to 5-6 with aqueous solutions of NaOH and H_2SO_4. This solution was transferred to a 250-ml separatory funnel, 10 ml of a 1 percent aqueous solution of a chelator (diethyldithiocarbamic acid, sodium salt) was added, the funnel was shaken for 2 minutes, and the extract was allowed to stand for 10 minutes. A 10-ml portion of water-saturated methyl isobutyl ketone (MIBK) was added, and the funnel was shaken for 2 minutes to extract the metals into the MIBK. The aqueous solution was drawn off, discarded, and the MIBK was collected in a 16-by-125-mm culture tube. This solution was aspirated into the flame of an atomic absorption spectrophotometer.

Recoveries of the metals were determined from the analyses of fish samples fortified at different levels with each metal. The overall mean from triplicate analyses for arsenic at three levels (0.1, 0.25, 0.5 ppm) was 82 percent with a standard deviation of 9.3 percent. The mean and standard deviations for lead (0.1, 1, 5 ppm) and cadmium (0.05, 0.25, 0.5 ppm) were 109 percent ± 21.0 percent and 99 percent ± 17.7 percent, respectively.

1972—Homogenized samples for mercury determinations were dried in a microwave oven for 15 minutes before combustion, but were otherwise analyzed as described for 1971. For lead and cadmium, 1-g subsamples of ground whole-body composites were dried in a beaker on a hotplate, charred with infrared lamps, and ashed in a muffle furnace at 500°C for 4 hours. After cooling, the residue was dissolved in 1 ml concentrated HNO_3, then heated until dry and white. To the cooled residue, 1 ml of concentrated HNO_3 was added, then diluted to 20 ml with water. The solution was warmed on a hotplate, cooled, and adjusted to a pH of 3 ± 0.2, then quantitatively transferred to a 125-ml separatory funnel with 2 ml water. A 1-ml portion of a 1 percent (w/v) aqueous solution of ammonium pyrrolidine-dithiodi-carbamate was added to the funnel and mixed. After 2 minutes, 10 ml of MIBK was added, the funnel was shaken for 1 minute, solvents were allowed to separate, and the lower aqueous layer was drawn off and discarded. A 10-ml solution of 5 percent HNO_3 was added to the funnel and shaken for 30 seconds. Solvents were allowed to separate, and the lower aqueous layer was collected. This sample solution was analyzed for both lead and cadmium, using a carbon rod atomizer on an absorption spectrophotometer.

Arsenic and selenium residues were determined in separate 1-g subsamples of the ground whole-body composites. Analyses for both followed the Jarrell-Ash (*7*) procedure with the following modifications: samples were placed in a Chromel wire sample holder and the holder was hung on the hook of a ground glass stopper placed in a 2-liter combustion flask containing 20 ml of 25 percent hydrochloric acid (HCl) solution for arsenic determinations, or 20 ml of a 1:1 (v/v) mixture of 50 percent HCl and 25 percent H_2SO_4 for selenium determinations. Flasks were flushed with oxygen, stoppered, and the contents were ignited with an infrared igniter. After combustion, flasks were allowed to stand 1 hour in order for the acid solution to entrain combustion products.

For the arsenic determination, the sample solution was transferred to a 100-ml pear-shaped flask and 20 ml of 40 percent (w/v) hydroxylamine hydrochloride was added; after the solution had been allowed to equilibrate for 15 minutes, 1 ml of a 6 percent aqueous solution of potassium iodide was added. After another 15 minutes, 2 ml of a 40 percent $SnCl_2$ solution was added and allowed to stand another 15 minutes; a Teflon-covered magnetic stirring bar was dropped into the flask and the flask was connected to an arsine generator. The solution was stirred briefly, 1 g of 20 mesh zinc was added and mixed for 2 minutes, and the generated arsine was swept with helium into the burner of an atomic absorption spectrophotometer.

Selenium sample solutions were decanted from the combustion flasks and rinsed with 20 ml acid (50 percent HCl and 25 percent H_2SO_4). A 10-ml portion of this solution (0.25 g sample equivalent) was placed in a pear-shaped flask with 30 ml of the HCl-H_2SO_4 acid mixture and 1 ml of stannous chloride ($SnCl_2$). A stirring bar was placed in this flask and the generator was connected as in the procedure for arsenic analysis. A magnetic stirrer was placed under the flask and 2 g of 20 mesh zinc was added; after 15 seconds of stirring, the hydrogen selenide generated was swept into the burner of the atomic absorption spectrophotometer.

Mercury recovery studies were made to compare microwave drying with the former P_2O_5 procedure for drying samples. Analysis of each of three samples using both drying procedures showed no significant differences ($P = 0.55$). Recoveries of lead and cadmium were determined by fortifying samples at varying levels ranging from 0.1 to 1 ppm for lead, and 0.01 to 0.1 ppm for cadmium. The overall mean recovery and standard deviation for lead was 90 percent ± 11.6 percent and 100 percent ± 13.6 percent for cadmium. For arsenic, the overall recovery from samples fortified with levels ranging from 0.05 to 0.3 ppm was 91 percent ± 18 percent. Selenium was determined by the procedure of Church and Robison (*3*). Recoveries of selenium by the procedure averaged 100 percent with a standard deviation of 15 percent.

1973—Mercury, lead, and cadmium were determined as in 1972. Arsenic was determined as in 1972, except that the

zinc used in generating arsine was 200-400 mesh in a slurry of distilled water (10 g zinc to 20 ml distilled water), and an electrodeless discharge lamp (EDL) and power supply were used in place of the hollow cathode lamp. Selenium was measured as described for 1972, but the light source was an EDL.

DETECTION LIMITS AND STANDARDS

The limits of detection of the metals in the composite fish samples were the same in all 3 years. Expressed as mg/kg wet weight, detection levels of each metal were mercury, 0.01; arsenic, 0.05; lead, 0.10; cadmium, 0.05; and selenium, 0.05. Analyses for metal residues were conducted on subsamples of composites prepared as described by Henderson et al. for laboratory C (*6*).

During all analyses, standard solutions of each metal were used for quantification and reagent blanks were used to detect possible contamination.

CROSS-CHECK ANALYSES

In cross-check analyses, total mercury was determined by the techniques described by the Joint Mercury Residues Panel (*10*) and modified as described by Henderson et al. (*5*). Arsenic and selenium residues were determined as described in the eleventh (*8*) and twelfth (*9*) editions, respectively, of the methods book of the Association of Official Analytical Chemists. Lead and cadmium residues were determined as follows: to a 12.5-g sample portion, 5 ml of 10 percent magnesium nitrate was added, the samples were then dried and charred on a hotplate and ashed overnight at 500°C. The samples were wetted with nitric acid, dried on a hotplate, and ashed again at 500°C for 20 minutes. After the sample had cooled, 2 ml concentrated HCL and 15 ml H_2O were added. Samples were boiled and stored in 50-ml volumetric flasks. Final determinations were made with a Perkin-Elmer model 303 spectrophotometer.

PRESENTATION OF RESULTS

The Denver Wildlife Research Center (DWRC) was contracted to conduct the initial analyses and the Wisconsin Alumni Research Foundation (WARF) was contracted to conduct cross-check analyses on selected samples. Also, DWRC conducted a methods check by repeating the analyses on several samples for all 3 years. Samples for cross-checking were selected according to results of initial analysis or the history of high residues at a particular station. A level of 0.5 mg/kg or greater was the criterion generally applied for selection. Mercury, arsenic, lead, and cadmium were analyzed in the samples from 1971, and selenium was added in 1972. In 1973, the rising costs of analytical work precluded the measurement of all metals. Therefore, only selected samples were analyzed for mercury, arsenic, lead, and cadmium, but all samples were analyzed for selenium residues to provide data for 2 consecutive years, 1972 and 1973. The initial and the cross-check data for 1971-73 are presented in Tables 1-3. Results of the initial run and of the in-house rerun by DWRC varied by less than one order of magnitude. For this reason and for a degree of brevity, rerun results are not presented.

The National Academy of Sciences recommends that to protect fish and predatory aquatic organisms, total mercury burdens in these organisms should not exceed 0.5 mg/kg net weight (*12*). For the present purposes, authors have considered that any level exceeding 0.5 mg/kg in whole body components is a high level at which mercury, arsenic, lead, cadmium, or selenium would harm fish. To show annual trends for these elements in all fish, each residue value from the initial analyses was placed into at least one of the following categories: composites analyzed, composites with residues, composites with residues at or below detectable levels, composites with residues between detectable levels and 0.5 mg/kg, or composites with residues above 0.5 mg/kg (Table 4).

Results

Mercury residues were present in all samples of fish collected (Tables 1-3). Of the 100 stations sampled, 25 in 1971, 12 in 1972, and 11 in 1973 yielded composites in which mercury concentrations exceeded 0.5 mg/kg. Henderson et al. (*5*) reported composites exceeding 0.5 mg/kg from 9 stations in 1969 and 20 in 1970. Only stations 1-50 were sampled in 1969. These data indicate a general increase of mercury contamination from 1969 to 1971 and a decrease from 1971 to 1973.

Henderson et al. (*5*) also pointed out that certain predator fishes such as bass, perch, and squawfish had the highest mercury residues. Of 12 species in the present study in which mean residues exceeded 0.5 mg/kg during any of the 3 years, 7 were predators: chain pickerel, white perch, smallmouth bass, largemouth bass, whitebass, sauger, and Northern squawfish; and 5 could be considered nonpredator, i.e., nonpiscivorous: bowfin, carp, yellow and brown bullhead, and channel catfish.

Residues of mercury, arsenic, and selenium were generally present in more than 90 percent of samples in the present study (Table 4); lead was detected in 56 percent and cadmium in 76 percent of the 584 composites analyzed in 1971.

Arsenic residues (Tables 1-3) were generally lower than those of mercury; concentrations in mg/kg ranged up to 3.40 in 1971, 1.70 in 1972, and 1.24 in 1973. Residues in excess of 0.5 mg/kg were detected in composites from eight stations during the 3 years. Unlike mercury residues, arsenic residues above 0.5 mg/kg were not confined to the predatory fishes.

Lead residues above 0.5 mg/kg were present in fish from 16 stations in 1971, 34 stations in 1972, and 10 stations in

1973 (Tables 1-3). The highest concentrations in mg/kg were detected in fish from the Hawaiian streams: 1.4 in 1971, 5.2 in 1972, and 1.4 in 1973. Like arsenic residues, lead residues above 0.5 mg/kg were not confined to the predatory fishes.

Composites with cadmium residues above 0.5 mg/kg were few in 1971 (less than 1 percent) and 1972 (4 percent), and, of the 75 selected samples analyzed in 1973, none exceeded 0.5 mg/kg (Table 4). This suggests a decrease in the level of detectable residues of this metal, particularly since authors biased these results by selecting the samples to be analyzed during 1973 from stations at which residues in some samples exceed 0.5 mg/kg during 1972. Like lead and arsenic, cadmium residues above 0.5 mg/kg are not restricted to the predatory fishes. Cadmium is an extremely dangerous metal that accumulates readily in fish, has chronic effects, and is considered a threat to fishery resources (*12*).

The selenium analyses conducted only in 1972 and 1973 showed residues in essentially all samples (Table 4). Residues exceeding 0.5 mg/kg were distributed equally between predatory and nonpredatory fishes. Naturally occurring selenium has been detected in various environmental segments, but the biological significance of selenium residues is unknown (*12*).

Excessive levels of metals, greater than 0.5 mg/kg, were found in some fish from most river systems, but such high levels apparently occurred more frequently in certain stations than in others. Of the 11 stations with excessive mercury levels in 1973, 6 were from the Atlantic coastal streams (one each on the Stillwater and Kennebec Rivers, Maine; Merrimac River, Mass.; Pee Dee River, S. C.; Savannah and Altamaha Rivers, Ga.); 1 on the Gulf coastal streams (Tombigbee River, Ala.); 1 on the Mississippi River system (Little River, Minn.); 3 on the Columbia River system (1 on the Willamette and 2 on the Columbia River). Of those 11 stations, 6 exceeded 0.5 mg/kg during 1972 and 1973 and 3 (Kennebec River, Maine; Savannah River, Ga.; Tombigbee River, Ala.) had residues that exceeded 0.5 mg/kg during all the years reported. McKim, who was quoted in a paper by Olson et al. (*14*), exposed brook trout to methyl-mercuric chloride and determined residues in muscle tissue to be within 90-100 percent of those in the whole body. This suggests that not only should the fish and their predators be protected, but that fish from some rivers should not be consumed by humans.

Olson et al. (*14*) exposed fathead minnows (*Pimephales promelas*) to concentrations of methylmercury ranging from 0.018 to 0.247 mg/liter. After 48 weeks, analysis of whole body samples showed mean residues ranging from 1.47 to 10.9 mg/kg total mercury. For the most part, these residues exceed levels of the present study. However, fish from the control water of Olson's experiment, in which no methylmercury was added and residues averaged <0.01 ppm, had mean residues of 0.21 mg/kg (95 percent confidence interval, 0.17 to 0.25 mg/kg); water used in the experiment was unfiltered water from Lake Superior. In 1973, residues in samples from Lake Superior, Bayfield, Wis., ranged from 0.09 to 0.40 mg/kg. Olson et al. (*14*) point out the potential significance of low concentrations of mercury in natural waters. In a biochemical evaluation of methylmercuric chloride, Christensen (*2*) showed only a decrease in glutamic oxaloacetic transaminase (GOT) activity (L-aspartate: 2-oxoglutarate aminotranslerase, EC 2.6.1.1.) in brook trout embryos, and a decrease in weight and an increase in GOT activity in alevins. He further concluded that the concentrations used (1.03 μg/liter) in the study would be unsafe for the species if exposure were extended from egg through adult. These laboratory studies combined with residue data in the present study suggest that the health of many species collected is in danger.

Arsenic levels exceeding 0.5 mg/kg were found in fish from five stations (Tombigbee River, Ala.; Lake Michigan; Lake Superior; Red River, Okla.); those from the Great Lakes had high residues more frequently than the others. A study by the National Academy of Sciences and National Academy of Engineering showed residues up to 100 mg/kg in shellfish; sea water normally contains 2 to 3 μg /liter (*12*). Authors point out that acute effects of arsenic have been investigated, but little is known about sublethal chronic effects except that arsenic is readily accumulated by marine organisms (*12*).

Geographic distribution of high levels of lead appears to have decreased between 1972 and 1973. For instance, of the 14 stations located from the Stillwater River, Maine, south to the Pee Dee River (Northern Atlantic coastal streams), 9 exceeded 0.5 mg/kg in 1972 and 4 exceeded 1.0 mg/kg in 1973. Only 5 of the 14 stations had concentrations exceeding 0.5 mg/kg and none had composites with residues above 1.0 mg/kg. On the Mississippi River system in 1972, 13 of 35 stations had composites with residues above 0.5 mg/kg; 6 of those exceeded 1.0 mg/kg and 1 exceeded 5.0 mg/kg. In 1973, only 1 station, Des Moines River, Iowa, exceeded 0.5 mg/kg. This trend generally prevailed where excessive lead residues were found in 1972. There are, however, two stations that do not follow this encouraging trend. In 1973, fish from the Columbia River at Grand Coulee, Wash., and Manoa Stream, Hawaii, had composites with residues of 1.0 mg/kg and 1.4 mg/kg, respectively. The former represents an increase and the latter represents only a slight decrease. The source of these residues should be investigated.

As indicated earlier, results of the in-house methods check by DWRC corresponded closely with the study each year; data are not included in this report. The in-house methods check represents the quality control of the laboratory and shows that the data presented are accurate

and can be interpreted within the limits of the methods used. Validity of the present findings is further enhanced by the fact that the cross-check data are from another laboratory which used slightly different techniques, yet agree closely with data here. Furthermore, examination of the results between replicated samples at one station also indicates that the residues are representative of environmental levels.

NAS and NAE have stated, ". . . at present, it is not possible to predict accurately the amount of total metal in any environment that may be lethal, biologically active or contributory to toxicity . . ." (*12*). Authors submit that the data presented in this program are indicative of environmental levels of arsenic, lead, cadmium, and water with a wide variation in such characteristics as hardness and pH, and that criteria should be established for each metal and water. For an update on the effects of pollution on fish, authors recommend an excellent review by McKim et al. (*11*) which includes chemical and biological methodology used, the effects of water quality, pesticides, industrial pollutants, including metals, and domestic and radioactive wastes.

Residues in river fish analyzed in the present study are based on wet weight, whole fish. The concentrations of residues in the edible portions would probably be lower.

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TABLE 1. *Concentrations of mercury, arsenic, lead, and cadmium in whole fish, 1971—National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight			
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium
Atlantic Coast Streams								
1. Stillwater River Old Town, Maine	White sucker	5	12.5	0.8	0.20	<0.05	0.26	<0.05
	White sucker (R)	5	12.5	0.8	0.28	<0.05	ND	<0.05
	Yellow perch	5	7.5	0.2	0.32	<0.05	ND	<0.05
	Yellow perch (R)	5	7.9	0.2	0.32	<0.05	0.26	0.05
	Chain pickerel	5	15.1	0.7	0.35	<0.05	0.16	<0.5
					(0.45)	(<0.05)	(<0.2)	(<0.05)
	Chain pickerel (R)	5	15.0	0.7	0.39	<0.05	ND	ND
51. Kennebec River Hinckley, Maine	White sucker	5	12.7	0.8	0.18	<0.05	ND	<0.05
	White sucker (R)	5	13.8	0.9	0.18	0.05	ND	ND
	Yellow perch	5	10.3	0.5	0.50	<0.05	ND	<0.05
					(0.83)	(<0.05)	(0.4)	(<0.05)
	Yellow perch (R)	5	9.1	0.3	0.50	<0.05	ND	ND
	Smallmouth bass	5	13.0	1.1	0.46	<0.05	0.21	ND
	Smallmouth bass (R)	2	14.4	1.4	1.20	<0.05	ND	<0.05
					(1.88)	(<0.05)	(0.5)	(<0.05)
52. Lake Champlain Burlington, Vt.	Pumpkinseed	5	7.3	0.4	0.12	0.10	ND	<0.05
					(0.23)	(0.08)	(0.4)	(<0.05)
	Pumpkinseed (R)	5	6.9	0.3	0.18	<0.05	0.78	ND
	Yellow perch	5	8.9	0.3	0.37	<0.05	0.57	<0.05
					(0.31)	(<0.05)	(0.7)	(0.06)
	Yellow perch (R)	5	10.0	0.4	0.31	<0.05	ND	ND
	Chain pickerel	3	16.2	1.0	0.39	0.05	0.13	<0.05
	Chain pickerel (R)	2	13.8	0.7	0.34	<0.05	0.11	<0.05
53. Merrimac River Lowell, Mass.	White sucker	5	12.0	0.7	0.15	<0.05	0.36	<0.05
	White sucker (R)	5	11.1	0.5	0.46	<0.05	0.36	<0.05
	Pumpkinseed	5	6.2	0.2	0.38	<0.05	0.24	ND
	Pumpkinseed (R)	5	4.4	0.1	0.42	<0.05	0.16	ND
	Yellow perch	5	10.7	0.6	0.14	<0.05	ND	ND
	Yellow perch (R)	5	10.7	0.6	0.42	<0.05	ND	ND
2. Connecticut River Windsor Locks, Conn.	White catfish	5	12.1	0.8	0.17	0.04	0.41	0.14
	White catfish (R)	5	12.9	1.1	0.21	0.06	0.51	0.17
	Yellow perch	5	8.8	0.3	0.25	<0.05	0.20	<0.05
	Yellow perch (R)	5	10.0	0.6	0.20	<0.05	0.12	<0.05
	White perch	4	8.6	0.4	0.38	<0.05	0.23	0.39
	White perch (R)	4	10.0	0.6	0.44	0.05	0.15	<0.05
3. Hudson River Poughkeepsie, N.Y.	Goldfish	5	9.4	0.8	0.06	0.11	1.30	0.12
	Goldfish (R)	5	9.9	0.8	0.19	0.08	0.52	0.15
	Pumpkinseed	5	6.1	0.1	0.13	0.07	ND	<0.05
	Pumpkinseed (R)	5	6.0	0.2	0.07	0.05	0.12	<0.05
	Largemouth bass	5	10.9	0.9	0.19	<0.05	ND	<0.05
	Largemouth bass (R)	5	10.8	0.9	0.10	0.05	ND	<0.05
54. Raritan River Highland Park, N.J.	Golden shiner	5	7.6	0.2	0.12	0.10	0.13	<0.05
	Golden shiner (R)	6	6.3	0.1	0.26	0.10	ND	<0.05
	White sucker	5	13.4	1.2	0.11	0.08	0.32	0.10
	White sucker (R)	5	12.3	1.0	0.18	<0.05	0.24	0.05
	White perch	5	9.7	0.7	0.34	0.08	0.16	<0.05
	White perch (R)	5	9.6	0.6	0.32	0.07	ND	<0.05
4. Delaware River Camden, N.J.	White sucker	5	14.6	1.3	0.06	0.06	0.51	0.06
	White sucker (R)	5	13.9	1.2	0.06	0.05	0.54	<0.05
	Brown bullhead	5	11.7	0.8	0.12	0.06	0.38	<0.05
	Brown bullhead (R)	5	10.9	0.7	0.04	0.06	0.36	<0.05
					(0.05)	(0.06)	(0.45)	(<0.05)
	White perch	5	9.5	0.5	0.25	0.06	0.78	<0.05
	White perch (R)	5	9.8	0.6	0.20	<0.05	0.47	<0.05
5. Susquehanna River Conowingo Dam, Md.	Carp	4	18.0	3.0	0.12	0.09	0.12	ND
	Carp (R)	4	18.9	3.3	0.05	0.20	ND	0.10
	Channel catfish	5	15.2	1.1	0.04	0.07	0.14	<0.05
	Channel catfish (R)	5	15.4	1.3	0.02	0.06	0.17	<0.05
	Yellow perch	5	8.6	0.3	0.08	0.06	ND	<0.05
	Yellow perch (R)	5	8.4	0.3	0.10	0.08	ND	<0.05
6. Potomac River Little Falls, Md.	Carp	5	17.2	2.6	0.26	0.13	0.11	0.08
	Carp (R)	5	15.7	2.0	0.19	0.11	0.21	0.11
	Redhorse[1]	5	13.5	1.0	0.18	<0.05	ND	0.06
	Redhorse (R)	5	14.7	1.2	0.15	0.06	ND	0.09
	Smallmouth bass	5	14.1	1.4	0.32	<0.05	ND	ND
	Smallmouth bass (R)	4	10.2	0.5	0.14	<0.05	ND	0.05
55. James River Richmond, Va.	Redhorse sucker	2	16.5	1.8	0.15	0.05	ND	ND
	Redhorse sucker (R)	2	16.0	1.6	0.10	<0.05	ND	0.23
	Channel catfish	2	21.5	3.6	0.23	<0.05	ND	0.05
	Channel catfish (R)	2	17.0	1.4	0.11	<0.05	ND	ND
	Largemouth bass	5	11.6	0.9	0.24	<0.05	ND	ND
	Largemouth bass (R)	5	8.6	0.3	0.23	<0.05	ND	ND

(*Continued next page*)

TABLE 1 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in whole fish, 1971 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight			
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium
7. Roanoke River Roanoke Rapids, N.C.	Redhorse	4	18.7	2.5	0.13	<0.05	ND	ND
	Redhore (R)	4	19.8	2.9	0.12	<0.05	ND	0.17
	Brown bullhead	3	9.7	0.3	0.06	<0.05	ND	ND
	Largemouth bass	5	10.5	0.7	0.14	0.10	ND	0.06
	Largemouth bass (R)	5	9.3	0.5	0.11	0.06	ND	ND
8. Cape Fear River Elizabethtown, N.C.	Gizzard shad	5	8.7	0.2	0.10	0.09	0.20	<0.05
	Gizzard shad	5	10.0	0.4	0.10	0.05	0.35	<0.05
	Brown bullhead	5	9.5	0.3	0.14	<0.05	0.10	ND
	Brown bullhead (R)	5	9.6	0.3	0.22	<0.05	0.13	<0.05
	Largemouth bass	3	11.1	3.6	0.46	0.09	0.15	ND
56. Pee Dee River Dongola, S.C.	White catfish	5	14.5	1.6	0.33	<0.05	ND	0.06
	White catfish (R)	5	14.9	2.0	0.36	0.05	ND	<0.05
	Bluegill	4	5.5	0.2	0.04	0.09	0.21	<0.05
	Bluegill (R)	4	5.0	0.1	ND	ND	ND	ND
	Bowfin	4	18.5	2.5	1.03	0.20	ND	ND
	Bowfin (R)	4	17.6	2.1	0.43	0.22	ND	ND
9. Cooper River Summerton, S.C.	Carp	2	23.2	6.8	0.04	0.08	ND	<0.05
	Carp (R)	2	23.5	7.3	0.29	0.05	0.11	ND
	Bluegill	5	6.5	0.2	0.12	0.05	ND	ND
	Bluegill (R)	5	6.2	0.2	0.08	0.12	ND	ND
	Largemouth bass	5	11.0	0.6	0.05	0.05	0.23	<0.05
	Largemouth bass (R)	5	11.2	0.8	0.12	0.05	0.21	ND
10. Savannah River Savannah, Ga.	Carp	2	20.3	4.1	ND (<0.05)	<0.05 (<0.05)	0.14 (0.3)	<0.05 (<0.05)
	Carp (R)	2	20.9	4.4	0.36 (0.41)	ND (<0.2)	ND (<0.05)	
	Bluegill	2	11.2	1.0	<0.05 (<0.05) 0.44	<0.05	ND	0.50
	Bluegill (R)	3	8.8	0.6	(0.54) 0.10	(0.12) 0.06	(0.8) 0.21	(<0.05) <0.05
	Largemouth bass	3	10.9	1.0	(0.28) 0.60	(0.10) 0.06	(0.3) ND	(<0.05) ND
	Largemouth bass (R)	4	10.9	0.7	(0.72) 0.34	(<0.05) <0.05	(<0.2) ND	(<0.05) ND
57. Altamaha River Doctortown, Ga.	Spotted sucker	4	17.2	2.2	0.23	0.06	0.16	0.12
	Spotted sucker (R)	4	18.2	2.7	0.22	0.06	ND	0.10
	Bluegill	5	7.6	0.4	0.12	0.09	ND	ND
	Bluegill (R)	5	7.4	0.4	0.12	0.09	ND	ND
	Largemouth bass	4	13.4	1.3	0.36	<0.05	ND	ND
	Largemouth bass (R)	4	12.2	1.1	0.43	<0.05	ND	<0.05
11. St. Johns River Welaka, Fla.	Striped mullet	2	21.3	4.1	ND	0.34	0.15	<0.05
	Striped mullet(R)	3	19.1	3.1	ND	0.26	ND	0.05
	Channel catfish	5	10.7	0.4	0.02	<0.05	ND	ND
	Channel catfish	4	11.1	0.4	ND	<0.05	ND	ND
	Largemouth bass	3	17.1	2.9	0.64	0.06	ND	ND
	Largemouth bass (R)	3	15.4	2.3	0.10	0.05	ND	<0.05
12. St. Lucie Canal Indiantown, Fla.	Channel catfish	3	16.6	1.8	0.09	<0.05	ND	ND
	Channel catfish (R)	2	21.8	3.8	0.13	<0.05	ND	0.06
	Bluegill	4	6.5	0.2	0.04	0.06	ND	ND
	Bluegill (R)	4	6.4	0.2	0.07	0.09	ND	ND
	Largemouth bass	4	11.5	1.2	0.26	0.08	ND	ND
	Largemouth bass (R)	4	12.4	1.2	0.32 0.35	0.10 0.09	0.13 ND	<0.05 0.05
Gulf Coast Streams								
58. Suwanee River Old Town, Fla.	Spotted sucker	4	12.5	1.0	0.15	<0.05	ND	<0.05
	Spotted sucker (R)	4	13.8	1.4	0.22	<0.05	ND	<0.05
	Redbreast sunfish	5	7.6	0.2	0.17	<0.05	ND	<0.05
	Redbreast sunfish (R)	5	7.9	0.3	0.12	<0.05	ND	<0.05
	Largemouth bass	4	13.4	1.6	0.42	0.22	ND	ND
	Largemouth bass (R)	4	12.1	1.4	0.76	<0.05	ND	<0.05
13. Apalachicola River Jim Woodruff Dam, Fla.	Spotted sucker	3	15.6	2.1	0.15	0.10	ND	<0.05
	Channel catfish	3	10.8	0.7	0.06	<0.05	ND	ND
	Channel catfish (R)	3	9.7	0.5	0.06	<0.05	ND	ND
	Largemouth bass	4	10.0	0.5	0.09	0.07	ND	ND
	Largemouth bass (R)	4	9.4	0.4	0.09	0.09	ND	ND
59. Alabama River Chrysler, Ala.	Striped mullet	4	16.1	2.0	0.02	0.24	ND	<0.05
	Striped mullet (R)	4	15.0	1.7	0.19	0.16	0.12	<0.05
	Bluegill	5	8.0	0.4	0.08	<0.05	0.14	<0.05
	Bluegill (R)	5	7.6	0.4	0.16	<0.05	ND	ND
	Largemouth bass	4	17.1	3.2	0.59	0.07	ND	0.10
	Largemouth bass (R)	5	16.6	2.6	0.09	0.07	ND	<0.05

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TABLE 1 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in whole fish, 1971 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight			
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium
14. Tombigbee River McIntosh, Ala.	Carp	3	19.7	3.9	0.10	0.07	ND	<0.05
	Carp (R)	3	19.6	3.8	0.42	0.11	ND	ND
	Striped mullet	3	15.8	1.9	0.07	0.50	ND	ND
	Striped mullet (R)	3	15.6	1.8	0.30	0.70	0.13	<0.05
	Largemouth bass	4	15.7	2.0	1.10	0.13	ND	<0.05
	Largemouth bass (R)	5	14.7	1.6	1.10	0.09	ND	ND
15. Mississippi River Luling, La.	Carp	3	14.2	2.1	0.04	0.08	0.15	<0.05
	Carp (R)	3	14.4	1.9	0.02	0.07	ND	<0.05
	Bigmouth buffalo	3	18.6	4.8	0.11	0.07	0.22	0.06
	Bigmouth buffalo (R)	3	19.2	4.9	0.15	0.12	0.23	<0.05
	Channel catfish	3	14.2	1.3	0.07	0.05	0.30	<0.05
	Channel catfish (R)	3	15.7	1.8	0.12	0.05	0.37	<0.05
60. Brazos River Richmond, Tex.	Smallmouth buffalo	2	21.4	7.0	0.17	0.07	0.13	<0.05
	Smallmouth buffalo (R)	3	19.1	4.0	0.09	0.06	0.19	<0.05
	Blue catfish	3	14.3	1.6	0.09	<0.05	0.26	<0.05
	Longnose gar	3	25.1	1.6	0.34	<0.05	ND	ND
	Spotted gar	3	22.4	2.1	0.44	0.05	0.10	<0.05
61. Colorado River Wharton, Tex.	River carpsucker	5	11.8	1.1	0.16	0.06	0.21	<0.05
	River carpsucker (R)	5	14.3	1.4	0.11	0.07	0.17	ND
	Channel catfish	3	15.5	1.0	0.05	<0.05	0.13	<0.05
	Flathead catfish	3	22.5	4.7	0.30	ND	<0.10	<0.05
	Longnose gar	3	26.1	1.7	0.24	ND	0.14	<0.05
	Longnose gar (R)	3	24.2	1.6	0.31	<0.05	0.12	<0.05
62. Nueces River Mathis, Tex.	Gizzard shad	6	9.7	0.4	0.06	0.10	0.10	<0.05
	Gizzard shad (R)	6	7.3	0.2	0.02	0.16	0.15	<0.05
	Blue catfish	6	12.8	0.6	0.11	<0.05	0.13	<0.05
	Blue catfish (R)	6	11.3	0.4	0.10	<0.05	0.16	<0.05
	Black crappie	6	7.0	0.3	0.06	0.16	<0.10	<0.05
	White crappie	6	8.7	0.3	0.13	0.14	0.11	<0.05
16. Rio Grande Brownsville, Tex.	Gizzard shad	3	9.6	0.3	0.02 (0.06)	0.32 (0.43)	0.20 (0.5)	<0.05 (0.06)
	Gizzard shad (R)	3	10.6	0.4	0.15	0.23	0.10	ND
	Channel catfish	3	13.4	1.1	0.10	<0.05	0.24	ND
	Channel catfish (R)	3	11.9	0.6	0.11	<0.05	0.26	ND
	Blue catfish	3	13.5	1.4	0.11	0.12	0.26	ND
	Blue catfish (R)	3	13.0	1.1	0.11 (0.08)	<0.05 (0.06)	0.44 (0.5)	ND (<0.05)
63. Rio Grande Elephant Butte, N. Mex.	Channel catfish	6	13.2	1.3	0.48	<0.05	ND	<0.05
	White bass	2	15.8	2.0	0.58	0.24	ND	<0.05
	White bass (R)	3	16.2	2.0	0.68	0.14	ND	ND
	Longear sunfish	5	4.9	0.1	0.03	0.22	ND	<0.05
	Largemouth bass	2	16.9	2.8	0.68	0.15	ND	<0.05
	Largemouth bass (R)	2	16.6	2.7	0.53	0.11	ND	ND
64. Rio Grande Alamosa, Colo.	Carp	3	10.1	0.5	0.02	<0.05	0.27	<0.05
	Carp (R)	3	10.4	0.5	0.30	0.06	0.14	ND
	White sucker	5	8.0	0.2	0.04	0.06	0.22	<0.05
	White sucker (R)	3	10.7	0.5	0.04	0.07	0.35	<0.05
	Brown trout	3	13.6	0.9	0.07	<0.05	0.20	ND
	Brown trout (R)	3	12.7	0.6	0.21	<0.05	0.19	<0.05
65. Pecos River Red Bluff Lake, Tex.	Gizzard shad	5	7.4	0.2	<0.01	0.08	0.11	<0.05
	Gizzard shad (R)	4	9.2	0.3	0.04	0.28	ND	ND
	Smallmouth buffalo	3	14.7	1.2	0.16	0.16	0.12	<0.05
	Smallmouth buffalo (R)	3	14.8	1.5	0.18	0.06	0.12	<0.05
	Channel catfish	3	15.8	1.3	0.06	<0.05	ND	<0.05
	Channel catfish (R)	3	17.3	1.8	0.17	<0.05	ND	<0.05
17. Genessee River Scottsville, N.Y.	White sucker	5	14.4	1.1	0.14	0.06	<0.10	<0.05
	White sucker (R)	4	14.1	1.0	0.16	0.08	0.10	<0.05
	Rock bass	5	8.0	0.4	0.32	<0.05	0.30	<0.05
	Rock bass (R)	5	7.5	0.4	0.28	0.05	<0.10	ND
	Walleye	5	19.3	3.0	0.64	0.08	0.10	<0.05
	Walleye (R)	5	13.4	0.9	0.28	0.11	0.12	ND
66. St. Lawrence River Massena, N.Y.	White sucker	5	13.9	1.1	0.12	0.05	0.14	ND
	White sucker (R)	5	14.1	1.2	0.11	0.05	0.21	ND
	Yellow perch	5	9.2	0.3	0.36	0.06	0.10	ND
	Yellow perch (R)	5	8.4	0.2	0.23	<0.05	0.19	ND
	Smallmouth bass	5	12.2	0.9	0.34	0.28	ND	ND
	Smallmouth bass (R)	5	12.1	0.9	0.38	0.34	ND	ND
18. Lake Ontario Port Ontario, N.Y. N.Y.	Yellow perch	5	11.4	0.8	0.65 (0.58)	0.15 (0.18)	0.20 (0.4)	<0.05 (<0.05)
	Yellow perch (R)	5	11.3	0.8	0.50	0.10	0.16	ND
	White perch	5	10.0	0.6	0.36	0.14	0.85	<0.05
	White perch (R)	5	9.6	0.6	0.46 (0.56)	0.14 (0.31)	1.40 (0.4)	<0.05 (<0.05)
	Rock bass	5	8.3	0.5	0.45 (0.45)	0.10 (0.12)	ND (0.4)	ND (<0.05)
	Rock bass (R)	5	8.4	0.6	0.52 (0.48)	0.10 (0.14)	0.51 (0.4)	<0.05 (<0.05)

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TABLE 1 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in whole fish, 1971 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight			
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium
19. Lake Erie Erie, Pa.	White sucker	5	14.6	1.3	0.13	0.11	ND	ND
	White sucker (R)	5	14.4	1.4	0.14	0.16	0.18	0.06
	Freshwater drum	5	13.3	1.1	0.29	0.11	0.20	<0.05
	Freshwater drum (R)	5	13.3	1.3	0.13	0.09	0.20	<0.05
	Yellow perch	5	9.5	0.5	0.09	<0.05	ND	<0.05
	Yellow perch (R)	5	9.0	0.4	0.13	<0.05	0.12	<0.05
20. Lake Huron Bay Port, Mich.	Carp	4	16.7	2.4	0.02	<0.05	ND	<0.05
	Carp (R)	4	17.7	2.7	0.04	0.08	0.15	<0.05
	Channel catfish	5	17.0	1.6	0.11	0.12	ND	<0.05
	Channel catfish (R)	5	17.3	1.7	0.12	0.16	0.11	<0.05
	Yellow perch	5	9.4	0.4	0.04	<0.05	0.11	ND
	Yellow perch (R)	5	9.1	0.3	0.02	<0.05	ND	ND
21. Lake Michigan Sheboygan, Wis.	Bloater	3	9.5	0.5	0.07	2.80	0.54	<0.05
	Bloater (R)	2	9.3	0.4	0.13	3.40	ND	<0.05
	Lake trout	5	26.0	6.4	0.52	1.00	ND	<0.05
	Lake trout (R)	5	25.1	6.6	0.49	1.30	0.10	0.05
	Yellow perch	5	9.8	0.3	0.16	0.07	0.15	ND
	Yellow perch (R)	3	9.6	0.3	0.15	0.07	0.13	ND
22. Lake Superior Bayfield, Wis.	Bloater	5	8.5	0.5	0.20	0.80	1.00	<0.05
	Bloater (R)	5	8.4	0.4	0.13	0.90	0.31	0.09
	Lake whitefish	5	19.7	2.4	0.01	0.60	0.13	<0.05
	Lake whitefish (R)	5	20.0	2.8	0.09	0.60	ND	0.20
	Lake trout	5	19.0	3.2	0.42	0.27	ND	<0.05
	Lake trout (R)	4	22.0	4.4	0.46	0.27	ND	<0.05
67. Allegheny River Natrona, Pa.	Carp	4	16.4	1.9	0.04	<0.05	0.30	0.07
	Carp (R)	4	18.8	3.8	0.12	0.06	0.13	0.07
	Yellow perch	4	9.6	0.5	0.27	<0.05	0.14	<0.05
	Yellow perch (R)	5	7.9	0.2	(0.10)	(<0.05)	(0.4)	(<0.05)
					0.08	ND	ND	<0.05
	Walleye	4	12.4	0.7	(0.08)	(<0.05)	(0.7)	(<0.05)
	Walleye (R)	5	16.4	1.5	0.19	<0.05	0.13	<0.05
					0.19	0.08	0.12	0.06
23. Kanawha River Winfield, W.Va.	Carp	5	11.3	0.9	0.01	<0.05	ND	ND
	Carp (R)	5	12.0	1.0	ND	<0.05	ND	ND
	Brown bullhead	5	10.9	0.8	0.08	<0.05	0.18	0.13
	Brown bullhead (R)	5	11.5	0.8	0.04	0.07	0.14	ND
	White crappie	5	9.2	0.5	0.09	<0.05	ND	<0.05
	White crappie (R)	5	9.2	0.05	0.14	<0.05	ND	ND
68. Wabash River New Harmony, Ind.	Carp	3	19.8	4.3	0.28	0.07	ND	0.12
	Carp (R)	3	19.2	3.5	0.25	0.07	ND	0.05
	Channel catfish	3	16.0	1.6	4.50	<0.05	0.16	<0.05
	Channel catfish (R)	3	17.7	1.9	0.29	<0.05	0.11	0.05
	White crappie	5	9.2	0.4	0.18	0.11	ND	<0.05
	White crappie (R)	5	9.5	0.4	0.16	0.08	ND	<0.05
24. Ohio River Marietta, Ohio	Carp	2	19.1	3.9	0.14	0.52	0.34	0.08
	Carp (R)	2	14.0	1.4	(0.11)	(0.40)	(0.3)	(0.07)
	Channel catfish	4	14.8	1.1	0.15	0.28	0.40	0.09
	Channel catfish (R)	4	13.1	0.7	0.19	<0.05	0.10	ND
	Largemouth bass	4	12.6	1.5	0.30	<0.05	0.28	<0.05
	Largemouth bass (R)	4	13.3	1.4	0.25	0.11	0.12	<0.05
					(0.26)	(0.07)	(0.3)	(<0.05)
					0.22	0.07	ND	ND
69. Ohio River Cincinnati, Ohio	Carp	5	15.3	1.9	0.09	<0.05	0.28	0.08
	Carp (R)	5	14.4	1.7	0.09	0.08	0.15	<0.05
	Channel catfish	4	14.5	1.3	0.17	ND	0.20	<0.05
	Channel catfish (R)	4	14.3	0.9	0.18	<0.05	0.16	<0.05
	Sauger	5	12.9	0.8	0.14	0.06	<0.10	<0.05
	Sauger (R)	5	12.7	0.7	0.13	0.07	<0.10	<0.05
70. Ohio River Metropolis, Ill.	Carp	4	18.4	3.6	0.23	0.25	ND	0.10
	Carp (R)	4	17.3	2.8	0.12	0.25	0.13	0.12
	Channel catfish	5	14.1	0.9	0.18	0.22	0.29	<0.05
	Channel catfish (R)	5	14.6	1.0	0.14	0.17	0.14	<0.05
	White crappie	5	10.4	0.7	0.18	0.13	ND	0.30
	White crappie (R)	5	10.1	0.6	0.42	0.16	ND	<0.05
25. Cumberland River Clarksville, Tenn.	Carp	4	10.8	0.5	0.11	0.06	ND	<0.05
	Carp (R)	4	9.5	0.4	0.05	<0.05	ND	<0.05
	Bluegill	4	5.5	0.1	0.09	ND	0.23	<0.05
	Bluegill (R)	4	6.0	0.1	0.04	<0.05	ND	<0.05
	Largemouth bass	2	9.6	0.6	0.10	0.10	ND	0.05

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TABLE 1 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in whole fish, 1971 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight			
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium
71. Tennessee River Savannah, Tenn. Tenn.	Carp	3	17.3	2.4	0.23	0.13	ND	<0.05
	Carp (R)	3	17.3	2.7	0.20	0.07	ND	<0.05
	Channel catfish	3	13.4	0.8	0.28	0.10	ND	<0.05
	Channel catfish (R)	4	12.5	0.7	0.34	0.08	0.12	<0.05
	Largemouth bass	3	12.9	1.2	0.24	0.21	ND	<0.05
	Largemouth bass (R)	3	12.9	1.1	0.14	0.18	ND	0.07
72. Wisconsin River Woodman, Wis.	Carp	3	18.7	3.4	0.25	0.05	<0.10	<0.05
	Carp (R)	4	20.5	4.0	0.19	0.06	ND	<0.05
	Channel catfish	4	16.3	1.4	0.20	ND	0.10	<0.05
	Channel catfish (R)	4	17.4	1.6	0.66 (0.19)	<0.05 (<0.05)	<0.10 (0.2)	<0.05 (<0.05)
	Sauger	4	11.3	0.4	0.55	<0.05	<0.10	<0.05
	Sauger (R)	4	13.9	1.0	1.10 (0.77)	<0.05 (<0.05)	ND (0.3)	ND (<0.05)
	Smallmouth bass	4	10.8	0.7	0.06 (0.46)	<0.05 (<0.05)	ND (<0.2)	ND (<0.05)
	Smallmouth bass (R)	4	14.6	1.7	0.99 (0.96)	<0.05 (<0.05)	<0.10 (<0.2)	<0.05 (<0.05)
73. Des Moines River Keosauqua, Iowa	Carp	5	12.5	0.9	0.01 (<0.05)	<0.05 (<0.05)	0.83 (0.2)	<0.05 (<0.05)
	Carp (R)	5	13.0	1.2	0.05	ND	0.32	<0.05
	Channel catfish	5	12.6	0.7	0.06	ND	0.11	ND
	Channel catfish (R)	5	13.0	0.7	0.05	ND	0.17	<0.05
	Walleye	5	13.6	0.8	0.16	<0.05	ND	ND
	Sauger	3	13.9	0.9	0.08	ND	0.11	<0.05
26. Illinois River Beardstown, Ill.	Carp	5	15.1	1.6	0.04	<0.05	ND	0.05
	Carp (R)	5	13.9	1.4	0.08	0.08	0.18	<0.05
	Bigmouth buffalo	3	16.4	3.0	0.06	0.13	ND	<0.05
	Bigmouth buffalo (R)	3	18.7	4.2	0.05	0.13	0.12	<0.05
	White crappie	4	8.9	0.4	0.08	0.16	ND	0.07
	White crappie (R)	4	9.4	0.5	0.05	0.18	ND	0.07
74. Mississippi River Little Falls, Minn.	White sucker	4	18.8	2.9	0.96	<0.05	ND	<0.05
	White sucker (R)	4	18.6	2.8	0.43	<0.05	ND	0.05
	Black bullhead	4	7.1	0.3	0.22	<0.05	0.10	<0.05
	Black bullhead (R)	4	7.0	0.3	0.26	<0.05	ND	ND
	Northern pike	3	18.2	1.4	0.42	<0.05	0.10	<0.05
	Northern pike	3	13.7	0.4	0.18	<0.05	ND	ND
27. Mississippi River Guttenburg, Iowa	Carp	5	17.9	3.5	0.15	<0.05	0.53	<0.05
	Carp (R)	5	19.5	4.4	0.18	<0.05	0.27	<0.05
	Bluegill	5	6.3	0.2	0.12 (0.12)	<0.05 (0.11)	0.30 (0.7)	ND (<0.05)
	Bluegill (R)	5	6.7	0.3	0.04	<0.05	0.15	<0.05
	Largemouth bass	5	13.8	2.0	0.26	<0.05	0.14	ND
	Largemouth bass (R)	5	13.2	1.9	0.33	<0.05	0.21	<0.05
75. Mississippi River Cape Girardeau, Mo.	Carp	5	18.5	3.0	0.06	0.05	ND	<0.05
	Carp (R)	5	18.6	3.2	0.15	0.07	0.22	0.08
	Channel catfish	5	16.0	1.2	0.12	<0.05	<0.10	<0.05
	White crappie	3	10.4	0.6	0.12	0.10	<0.10	<0.05
	White crappie (R)	2	11.8	1.2	0.10	0.16	ND	ND
76. Mississippi River Memphis, Tenn.	Carp	2	21.3	5.2	0.06	0.26	0.17	0.07
	Carp (R)	2	20.8	5.0	0.06	0.12	0.12	0.06
	Carpsucker	2	18.5	4.0	0.10	0.11	ND	<0.05
	Carpsucker (R)	2	17.0	2.8	0.08	0.37	0.13	<0.05
28. Arkansas River Pine Bluff, Ark.	Carp	2	16.9	2.1	0.09	0.05	ND	0.05
	Carp (R)	2	17.7	2.4	0.08	<0.05	ND	0.07
	Smallmouth buffalo	2	17.4	3.3	0.03	0.08	ND	<0.05
	Smallmouth buffalo (R)	2	18.3	3.5	0.14	0.33	ND	0.06
	Flathead catfish	2	19.4	2.8	0.16	<0.05	ND	0.06
	Flathead catfish (R)	2	21.6	4.8	0.48	<0.05	ND	0.05
29. Arkansas River Keystone Reservoir, Okla.	Carp	5	12.8	0.8	0.12	<0.05	<0.10	<0.05
	Carp (R)	5	14.6	1.4	0.08	0.13	0.13	<0.05
	Channel catfish	5	16.1	1.1	0.14	0.26	0.10	<0.05
	Channel catfish (R)	5	16.7	1.2	0.15	0.07	0.11	<0.05
	Bluegill	5	5.7	0.1	0.07	0.07	<0.10	ND
	Bluegill (R)	4	5.6	0.1	0.03	<0.05	<0.15	<0.05
77. Arkansas River John Martin Reservoir, Colo.	Carp	5	13.7	1.2	2.70 (<0.05)	<0.05 (<0.05)	0.13 (<0.2)	<0.05 (<0.05)
	Carp (R)	5	13.5	1.2	0.04 (<0.05)	<0.05 (<0.05)	<0.10 (<0.2)	ND (<0.05)
	Channel catfish	4	15.0	1.3	0.05	<0.05	0.15	<0.05
	Channel catfish (R)	3	13.2	0.8	0.06	ND	0.26	<0.05
	Black bullhead	5	9.9	0.6	0.16	ND	0.16	<0.05
	Black bullhead (R)	3	9.2	0.4	0.11	ND	0.10	ND

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TABLE 1 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in whole fish, 1971 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight			
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium
78. Verdigris River Oologah, Okla.	Carp	5	10.6	0.5	0.03	0.09	0.80	<0.05
	Carp (R)	5	11.1	0.7	0.04	<0.05	0.10	<0.05
	Bluegill	5	6.8	0.1	0.04	0.07	ND	ND
	Bluegill (R)	5	6.2	0.1	0.07	<0.05	ND	ND
	Largemouth bass	5	12.1	0.7	0.07	0.19	0.20	ND
	Largemouth bass (R)	5	10.3	0.4	0.06	0.21	ND	ND
79. Canadian River Eufaula, Okla.	Carp	5	13.9	1.3	0.12	0.09	ND	<0.05
	Carp (R)	5	14.9	1.4	0.08	0.11	ND	<0.05
	Bluegill	5	5.8	0.2	0.02	0.06	ND	ND
	Bluegill (R)	5	5.9	0.2	0.03	<0.05	<0.10	ND
	Channel catfish	4	15.8	1.4	0.15	<0.05	ND	<0.05
	Channel catfish (R)	4	15.4	1.4	0.16	ND	<0.05	ND
30. White River De Valls Bluff, Ark.	Carp	2	19.1	3.5	0.13	<0.05	ND	0.05
	Carp (R)	2	22.4	6.5	0.24	0.11	0.11	0.17
	Bigmouth buffalo	2	18.6	3.9	0.11	0.15	ND	<0.05
	Bigmouth buffalo (R)	2	16.6	2.4	0.03	0.19	ND	<0.05
	Channel catfish	2	22.9	5.0	0.38	0.11	ND	<0.05
	Channel catfish (R)	2	19.6	3.1	0.12	0.14	ND	<0.05
80. Yazoo River Redwood, Miss.	Carp	2	18.8	4.0	0.14	0.05	ND	0.05
	Carp (R)	1	21.4	5.5	0.12	<0.05	ND	0.07
	Smallmouth buffalo	2	16.0	2.5	0.19	0.08	0.22	<0.05
	Smallmouth buffalo (R)	2	16.1	2.5	0.19	<0.05	0.20	<0.05
	Channel catfish	2	20.1	2.3	0.16	ND	ND	<0.05
81. Red River Alexandria, La.	Smallmouth buffalo	2	16.1	2.3	0.09	0.07	0.15	<0.05
	Smallmouth buffalo (R)	2	15.5	1.9	0.23	<0.05	ND	ND
	Freshwater drum	3	13.5	1.2	0.20	0.09	ND	<0.05
	Freshwater drum (R)	2	14.2	1.3	0.16	0.09	ND	<0.05
	White catfish	3	14.9	1.2	0.10	<0.05	0.15	0.06
	White catfish (R)	2	14.7	1.2	0.03	<0.05	0.10	<0.05
82. Red River Lake Texoma, Okla.	Carp	3	20.6	3.9	0.11	<0.05	0.13	<0.05
	Carp (R)	3	19.5	3.4	0.01	<0.05	0.18	0.05
	Bluegill	4	7.1	0.3	0.02	0.10	0.15	<0.05
	Bluegill (R)	4	6.8	0.3	0.02	0.07	<0.10	ND
	Largemouth bass	3	12.5	0.8	0.08	0.22	0.16	<0.05
	Largemouth bass (R)	3	14.5	1.4	0.06	<0.05	0.14	<0.05
83. Missouri River Hermann, Mo.	Carp	5	17.5	2.4	0.05	<0.05	0.11	0.08
	Carp (R)	5	17.2	2.4	0.03	<0.05	0.14	0.13
	Smallmouth buffalo	3	15.7	2.2	0.08	0.06	0.35	<0.05
	Smallmouth buffalo (R)	3	17.0	2.9	0.18	<0.05	0.19	<0.05
31. Missouri River Nebraska City, Nebr.	Carp	5	17.4	2.8	0.06	<0.05	0.10	0.07
	Carp (R)	5	16.3	2.2	0.06	0.06	0.11	0.06
	Goldeye	5	14.1	1.0	0.14	ND	0.23	<0.05
	Goldeye (R)	5	13.7	0.9	0.10	ND	0.20	<0.05
	White crappie	5	9.5	0.5	0.08	0.14	ND	<0.05
	White crappie (R)	5	8.4	0.3	0.04	0.08	ND	ND
32. Missouri River Garrison Dam, N. Dak.	White sucker	3	13.2	0.8	0.12	0.08	ND	<0.05
	White sucker (R)	3	13.5	0.8	0.10	0.17	ND	ND
	Goldeye	5	12.5	0.5	0.17	0.22	ND	<0.05
	Goldeye (R)	5	12.2	0.4	0.74	0.24	ND	ND
	Walleye	3	18.3	2.1	0.17	0.20	0.13	<0.05
	Walleye (R)	3	18.3	2.2	0.20	0.14	0.13	<0.05
33. Missouri River Great Falls, Mont.	Goldeye	5	11.8	0.6	0.18	0.08	ND	<0.05
	Goldeye (R)	5	11.8	0.6	0.13	0.24	0.10	0.05
	Redhorse	5	17.2	2.2	0.18	0.08	0.10	0.23
	Redhorse (R)	5	17.5	2.3	0.18	0.06	0.11	0.20
	Sauger	5	10.8	0.4	0.19	<0.05	ND	<0.05
	Sauger (R)	4	9.9	0.3	0.12	<0.05	ND	<0.05
84. Big Horn River Hardin, Mont.	Carp	5	15.3	2.4	0.28	<0.05	ND	0.09
	Carp (R)	5	15.8	2.7	0.12	0.09	ND	0.13
	Goldeye	5	11.0	0.6	0.23	0.07	ND	<0.05
	Goldeye (R)	5	10.8	0.5	0.26	<0.05	ND	<0.05
	Carpsucker	5	12.0	1.1	0.10	0.30	ND	ND
	Carpsucker (R)	5	11.5	0.9	0.13	0.29	ND	<0.05
85. Yellowstone River Sidney, Mont.	Goldeye	5	10.8	0.6	0.08	0.28	ND	<0.05
	Goldeye (R)	5	10.9	0.6	0.09	0.18	0.10	<0.05
	Carpsucker	4	13.2	1.7	0.13	0.17	0.10	<0.05
	Carpsucker (R)	4	11.8	1.2	0.02	0.14	<0.10	<0.05
	Walleye	3	13.4	1.2	0.20	0.06	<0.10	<0.05
	Walleye (R)	3	12.5	0.6	0.13	<0.05	<0.10	<0.05
86. James River Olivet, S. Dak.	Carp	3	18.3	2.7	0.05 (0.09)	<0.05 (<0.05)	ND (0.2)	0.05 (<0.05)
	Carp (R)	3	18.0	2.6	0.07	<0.05	0.11	<0.05

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TABLE 1 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in whole fish, 1971 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight			
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium
	Goldeye	5	13.2	0.9	0.06 (0.09)	<0.05 (<0.05)	0.24 (0.2)	ND (<0.05)
	Goldeye (R)	5	13.2	0.8	0.32 (0.12)	<0.05 (<0.05)	ND (<0.2)	ND (<0.05)
	Channel catfish	3	13.5	1.0	0.11	0.10	0.14	ND
	Channel catfish (R)	3	14.5	1.2	0.06	<0.05	ND	ND
87. North Platte River Lake McConaughy, Nebr.	Carp	5	14.9	2.1	0.21	0.24	ND	<0.05
	Carp (R)	5	16.4	2.1	0.10	0.24	0.13	<0.05
	Channel catfish	5	17.4	1.8	0.25	0.14	ND	<0.05
	Channel catfish (R)	5	19.8	2.4	0.16	0.17	ND	<0.05
	Walleye	5	16.5	1.9	0.14	0.41	ND	0.54
	Walleye (R)	5	15.9	1.6	0.18	1.50	ND	<0.05
88. South Platte River Brule, Nebr.	Carp	5	18.1	2.5	0.14	ND	0.38	0.05
	Carp (R)	5	17.3	2.4	0.12	0.06	ND	<0.05
	White sucker	5	12.8	0.8	0.10	0.05	0.15	ND
	White sucker (R)	5	12.3	0.8	0.10	0.08	ND	ND
	Black bullhead	5	8.4	0.4	0.34	<0.05	ND	ND
	Black bullhead (R)	5	8.3	0.3	0.14	<0.05	ND	ND
89. Platte River Louisville, Nebr.	Carp	5	16.4	2.0	0.02	<0.05	0.16	0.22
	Carp (R)	5	16.6	2.0	0.12	<0.05	<0.10	0.07
	Channel catfish	5	12.1	0.5	0.08	ND	0.13	<0.05
	Channel catfish (R)	5	10.2	0.4	0.16	ND	0.22	<0.05
	White crappie	3	9.8	0.5	0.11	0.08	<0.10	<0.05
	White crappie (R)	3	8.1	0.3	0.15	0.08	<0.10	ND
90. Kansas River Bonner Springs, Kans.	Carp	4	18.7	3.1	0.10	<0.05	0.11	<0.05
	Carp (R)	5	13.6	1.4	0.05	0.09	ND	<0.05
	Gizzard shad	5	7.8	0.3	0.04	0.14	0.10	<0.05
	Gizzard shad (R)	5	7.2	0.3	0.09	0.13	ND	<0.05
	Channel catfish	5	8.1	0.1	0.05	<0.05	0.27	<0.05
	Channel catfish (R)	5	7.8	0.1	0.08	<0.05	0.28	<0.05
Hudson Bay Drainage								
34. Red River Noyes, Minn.	Goldeye	5	13.6	0.8	0.19	<0.05	0.20	<0.05
	Goldeye (R)	5	13.0	0.8	0.18	<0.05	ND	<0.05
	Channel catfish	1	18.0	1.9	0.14	<0.05	0.11	<0.05
	Sauger	5	11.6	0.4	0.12	0.05	0.11	<0.05
	Sauger (R)	5	11.0	0.3	0.62	<0.05	0.10	0.15
Colorado River System								
35. Green River Vernal, Utah	Carp	4	13.7	1.5	0.06	<0.05	ND	ND
	Carp (R)	4	15.2	2.0	0.10	<0.05	ND	<0.05
	Flannelmouth sucker	4	16.4	1.4	0.10	0.13	0.18	<0.05
	Flannelmouth sucker (R)	4	16.1	1.4	0.19	0.09	0.24	<0.05
	Channel catfish	5	8.3	0.2	0.10	<0.05	0.11	0.12
	Channel catfish (R)	5	8.6	0.2	0.12	<0.05	ND	<0.05
36. Colorado River Imperial Reservoir, Ariz.	Carp	3	15.9	2.3	ND	0.08	0.14	<0.05
	Carp (R)	3	18.1	2.9	ND	ND	ND	ND
	Redear sunfish	5	7.6	0.3	ND	0.14	ND	<0.05
	Redear sunfish (R)	5	7.7	0.3	0.02	0.08	ND	ND
	Largemouth bass	4	8.7	0.4	0.79	0.13	ND	<0.05
	Largemouth bass (R)	3	10.2	0.5	0.02	<0.05	ND	ND
91. Colorado River Havasu Lake, Ariz.	Carp	3	13.7	1.5	0.01	<0.05	0.18	ND
	Carp (R)	4	14.1	1.3	0.02	<0.05	0.12	ND
	Channel catfish	3	16.5	1.4	0.01	0.29	0.15	<0.05
	Channel catfish (R)	4	15.8	1.2	0.02	0.13	ND	<0.05
	Black crappie	3	7.8	0.3	0.04	0.11	ND	ND
	Black crappie (R)	4	8.6	0.4	0.01	0.16	ND	ND
92. Colorado River Lake Mead, Nev.	Carp	3	18.0	2.8	0.06	0.10	1.10	0.14
	Channel catfish	3	14.9	1.1	0.03	0.06	ND	ND
	Channel catfish (R)	2	13.9	0.8	0.08	<0.05	0.10	<0.05
	Largemouth bass	3	13.1	1.5	0.02	0.27	ND	<0.05
	Largemouth bass (R)	3	11.3	0.4	0.52	0.18	ND	<0.05
93. Colorado River Lake Powell, Ariz.	Carp	5	13.2	0.9	0.70	0.11	0.13	0.27
	Carp (R)	5	13.0	0.8	0.10	0.08	ND	0.28
	Largemouth bass	4	13.3	1.4	0.20	0.50	0.16	<0.05
	Largemouth bass (R)	3	15.2	2.3	0.33	0.30	ND	<0.05
	Rainbow trout	3	21.1	4.9	0.15	0.26	0.65	<0.05
	Rainbow trout (R)	4	19.4	3.7	0.05	0.13	0.14	<0.05
94. Gila River San Carlos Reservoir, Ariz.	Carp	3	12.8	0.9	0.20	0.18	0.16	<0.05
	Carp (R)	5	11.7	0.7	0.06	0.17	0.22	<0.05
	Channel catfish	3	9.2	0.2	0.10	<0.05	0.16	<0.05
	Channel catfish (R)	5	12.6	0.5	0.12	<0.05	0.20	<0.05
	Largemouth bass	3	14.4	1.4	0.25	0.14	0.13	<0.05

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TABLE 1 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in whole fish, 1971 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight			
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium
Interior Basins								
37. Truckee River	Carp	5	15.5	1.7	0.64	0.09	ND	<0.05
Fernley,	Carp (R)	5	14.5	1.5	0.46	0.08	ND	<0.05
Nev.	Brown bullhead	3	8.9	0.4	0.20	ND	ND	<0.05
	Brown bullhead (R)	3	9.0	0.4	0.19	0.11	ND	<0.05
	Largemouth bass	2	10.7	0.8	0.42	0.05	0.15	0.23
	Largemouth bass (R)	2	11.4	1.0	0.52	0.05	ND	<0.05
38. Utah Lake	Carp	5	15.2	1.8	0.01	0.26	0.10	<0.05
Provo,	Carp (R)	5	13.5	1.3	ND	0.12	0.11	<0.05
Utah	Black bullhead	5	10.1	0.6	0.02	0.06	0.20	ND
	Black bullhead (R)	5	10.9	0.7	0.02	0.06	0.22	ND
	White bass	5	8.9	0.3	0.04	0.15	0.30	ND
	White bass (R)	5	8.4	0.3	0.08	0.20	0.41	ND
95. Bear River	Carp	5	14.3	2.1	0.10	0.08	ND	0.08
Preston,	Carp (R)	5	14.4	2.3	0.12	0.11	ND	<0.05
Idaho	Largescale sucker	5	16.6	2.2	0.20	0.08	0.12	<0.05
	Largescale sucker (R)	5	17.5	2.4	0.24	0.09	ND	<0.05
	Yellow perch	5	8.0	0.3	0.03	<0.05	ND	<0.05
	Yellow perch (R)	5	8.1	0.3	0.15	ND	0.13	<0.05
California Streams								
39. Sacramento River	Carp	5	13.0	1.4	0.16	0.19	0.19	0.08
Sacramento,	Carp (R)	5	12.7	1.3	0.10	0.29	0.14	<0.05
Calif.	White catfish	5	9.1	0.4	0.13	0.08	<0.10	<0.05
	White catfish (R)	5	9.4	0.5	0.13	0.12	0.50	<0.05
					(0.16)	(0.12)	(0.3)	(<0.05)
	Largemouth bass	5	12.5	1.3	0.18	0.07	<0.10	<0.05
	Largemouth bass (R)	5	11.3	1.0	0.12	<0.05	<0.10	<0.05
40. San Joaquin River	Carp	5	12.9	1.4	0.07	0.06	0.14	<0.05
Los Banos,	Carp (R)	5	11.9	1.4	0.02	<0.05	<0.10	<0.05
Calif.	Channel catfish	3	15.6	2.4	0.09	0.06	<0.10	ND
	Channel catfish (R)	3	14.2	2.1	0.12	0.08	0.11	<0.05
	Black crappie	5	10.2	0.8	0.04	0.42	<0.10	ND
	Black crappie (R)	5	10.0	0.8	0.01	0.29	<0.10	<0.05
Columbia River System								
43. Salmon River	Carp	4	15.4	2.4	0.23	0.11	ND	<0.05
Riggins,	Largescale sucker	5	15.3	1.7	0.36	0.12	ND	ND
Idaho	Largescale sucker (R)	5	15.8	1.8	0.19	0.15	0.14	0.21
	Northern squawfish	3	11.2	0.6	1.20	<0.05	ND	<0.05
	Northern squawfish (R)	3	13.9	1.2	0.42	0.20	ND	ND
	Smallmouth bass	3	11.3	1.0	0.36	<0.05	ND	<0.05
41. Snake River	Largescale sucker	5	12.6	1.0	0.08	0.06	<0.10	<0.05
Hagerman,	Largescale sucker (R)	5	13.0	1.0	0.05	0.08	<0.10	<0.05
Idaho	Peamouth chub	5	9.4	0.3	0.08	<0.05	<0.10	<0.05
	Peamouth chub (R)	5	9.5	0.4	0.10	<0.05	<0.10	<0.05
	Northern squawfish	5	14.4	1.3	0.28	0.06	ND	<0.05
	Northern squawfish (R)	5	14.3	1.3	0.35	ND	<0.10	<0.05
42. Snake River	Carp	5	14.9	2.0	0.36	<0.05	0.11	0.09
Lewiston,	Carp (R)	5	14.5	2.4	0.25	0.22	0.11	<0.05
Idaho	Northern squawfish	3	14.0	1.2	1.30	<0.05	ND	ND
	Northern squawfish (R)	3	14.0	1.2	0.89	<0.05	ND	0.05
	Smallmouth bass	5	11.2	1.1	0.28	0.06	ND	ND
	Smallmouth bass (R)	5	10.4	0.7	0.28	0.06	ND	ND
96. Snake River	Carp	5	13.1	1.6	0.19	0.08	0.11	0.11
Ice Harbor,	Carp (R)	5	12.4	1.6	0.24	0.14	<0.10	0.05
Wash.	Largescale sucker	5	14.1	1.1	0.14	0.24	<0.10	<0.05
	Largescale sucker (R)	5	13.5	1.0	0.14	0.22	0.12	<0.05
	Channel catfish	5	14.3	1.6	0.26	0.10	<0.10	<0.05
	Channel catfish (R)	5	14.7	1.9	0.60	0.10	<0.10	0.13
44. Yakima River	Carp	5	11.9	1.1	0.14	0.06	ND	ND
Granger,	Carp (R)	5	11.9	1.2	0.21	<0.05	ND	<0.05
Wash.	Largescale sucker	5	14.0	1.2	0.07	0.09	0.12	<0.05
	Largescale sucker (R)	5	14.1	1.2	0.09	0.10	ND	ND
	Black crappie	5	7.4	0.3	0.06	<0.05	ND	<0.05
	Black crappie (R)	5	7.4	0.3	0.12	<0.05	ND	ND
45. Willamette River	Largescale sucker	5	15.9	1.8	0.28	0.05	ND	<0.05
Oregon City,	Largescale sucker (R)	5	15.8	1.8	0.32	0.05	<0.10	ND
Oreg.	Northern squawfish	3	13.7	1.2	1.10	<0.05	ND	ND
	Northern squawfish (R)	3	13.5	1.1	0.99	<0.05	ND	<0.05

(*Continued next page*)

TABLE 1 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in whole fish, 1971 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight			
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium
46. Columbia River Bonneville Dam, Oreg.	Carp	5	11.7	1.0	0.05	0.15	ND	0.11
	Carp (R)	5	11.3	0.9	0.05	0.13	0.12	0.05
	Largescale sucker	5	16.2	1.8	0.21	0.12	0.11	<0.05
	Largescale sucker (R)	4	15.8	1.8	0.19	0.28	0.19	<0.05
	Northern squawfish	5	13.6	1.3	0.84	<0.05	ND	<0.05
	Northern squawfish (R)	5	14.6	1.4	0.76	0.05	ND	<0.05
97. Columbia River Pasco, Wash.	Carp	5	12.3	1.3	0.08	0.06	0.34	0.08
	Carp (R)	5	12.1	1.3	0.07	<0.05	0.40	0.12
	Largescale sucker	5	17.2	2.0	0.06	0.15	0.52	0.13
	Largescale sucker (R)	5	17.1	2.1	0.06	0.16	0.38	0.07
	Northern squawfish	5	12.2	0.8	0.15	<0.05	0.18	0.06
	Northern squawfish (R)	5	11.6	0.7	0.16	<0.05	0.11	<0.05
98. Columbia River Grand Coulee, Wash.	Largescale sucker	5	13.1	1.0	0.08	0.15	0.58	0.10
	Largescale sucker (R)	5	13.5	1.1	0.03 (<0.05)	0.18 (0.18)	0.90 (0.7)	0.13 (0.08)
	Northern squawfish	5	14.2	1.4	0.22	ND	0.26	0.23
	Walleye	4	16.1	2.0	0.15	0.07	0.12	0.07
	Walleye (R)	5	16.9	2.1	0.15	0.06	<0.10	<0.05
Pacific Coast Streams								
47. Klamath River Hornbrook, Calif.	Klamath sucker	4	14.3	1.6	0.24	0.12	ND	<0.05
	Klamath sucker (R)	3	15.5	2.2	0.28	0.10	0.11	0.17
	Brown bullhead	5	8.6	0.3	0.09	<0.05	ND	<0.05
	Brown bullhead (R)	5	8.6	0.4	0.06	<0.05	ND	ND
	Yellow perch	5	7.7	0.2	0.20	<0.05	ND	0.07
	Yellow perch (R)	5	7.6	0.2	0.18	<0.05	0.15	0.12
48. Rogue River Gold Ray Dam, Oreg.	Bridgelip sucker	5	12.7	1.2	0.08	0.06	0.11	<0.05
	Bridgelip sucker (R)	4	13.8	1.4	0.15	0.06	ND	0.06
	Brown bullhead	5	10.4	0.6	0.25	<0.05	ND	ND
	Brown bullhead (R)	5	10.2	0.5	0.30	<0.05	ND	<0.05
	Black crappie	4	9.0	0.5	0.14	<0.05	ND	<0.05
	Black crappie (R)	3	9.0	0.6	0.14	<0.05	ND	<0.05
Alaskan Streams								
49. Chena River Fairbanks, Alaska	Longnose sucker	3	14.1	1.6	0.05	0.06	0.29	<0.05
	Longnose sucker (R)	3	14.4	1.6	0.06	0.11	0.22	<0.05
	Round whitefish	3	10.9	0.5	0.07	<0.05	0.24	<0.05
	Round whitefish (R)	3	12.5	0.7	0.04	<0.05	ND	ND
	Arctic grayling	3	11.5	0.7	0.06	<0.05	0.19	ND
	Arctic grayling (R)	3	12.4	0.9	0.05	<0.05	0.23	<0.05
50. Kenai River Soldatna, Alaska	Round whitefish	5	13.8	0.8	0.04	0.14	0.11	<0.05
	Round whitefish (R)	5	11.7	0.5	0.06	0.18	ND	<0.05
	Lake trout	5	16.4	1.2	0.18	0.11	ND	<0.05
	Lake trout (R)	5	16.7	1.2	0.23	0.06	ND	<0.05
	Rainbow trout	5	11.1	0.6	0.06	0.16	ND	0.07
	Rainbow trout (R)	2	10.4	0.5	0.05	0.10	ND	<0.05
Hawaiian Streams								
99. Waikele Stream Waipahu, Hawaii	Tilapia	5	5.5	0.1	0.04 (0.07)	0.07 (0.09)	1.40 (1.7)	0.10 (0.09)
	Tilapia (R)	5	5.2	0.1	0.05	<0.05	0.90	0.05
	Cuban limia	10	3.3	ND	0.07 (0.07)	0.06 (0.06)	ND (0.4)	ND (<0.05)
	Cuban limia (R)	10	3.2	ND	0.07	<0.05	0.19	<0.05
	Chinese catfish	4	8.0	0.2	0.14	0.14	0.35	0.12
	Chinese catfish (R)	4	7.9	0.2	0.19	0.28	0.14	<0.05
100. Manoa Stream Honolulu, Hawaii	Tilapia	2	9.2	0.6	0.02	0.30	0.30	<0.05
	Tilapia (R)	2	9.5	0.5	0.05	0.11	0.12	ND
	Cuban limia	8	3.3	ND	ND	ND	ND	ND
	Cuban limia (R)	10	3.1	ND	0.06	0.11	0.24	<0.05
	Chinese catfish	2	10.3	0.4	0.11	<0.05	0.28	0.10
	Chinese catfish (R)	4	9.8	0.3	0.10	ND	0.12	<0.05

Note: R = replicate sample.
ND = not detected.
Numbers in parentheses are results of cross-check analyses.
[1] Redhorse = *Moxostoma* sp.

TABLE 2. *Concentrations of mercury, arsenic, lead, cadmium, and selenium in whole fish, 1972 —National Pesticide Monitoring Program*

Station Number and Location	Species	Average Size		Residues, mg/kg wet weight				
		No. Fish	Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium	Selenium
Atlantic Coast Streams									
1. Stillwater River Old Town, Maine	White sucker	5	13.5	1.0	0.49	0.32	0.22	<0.05	0.13
	Chain pickerel	5	14.1	0.56	0.62	<0.05	0.14	<0.05	0.05
	Yellow perch	5	8.9	0.31	0.50	<0.05	0.60	<0.05	0.25
	Yellow perch (R)	5	8.9	0.32	0.62	<0.05	0.40	<0.05	0.07
51. Kennebec River Hinckley, Maine	Smallmouth bass	5	11.2	0.6	0.99 (0.78)	<0.05 (0.05)	0.20 (<0.20)	<0.05 (0.05)	0.08 (0.35
	White perch	5	8.5	0.3	0.23	<0.05	0.30	<0.05	0.76
	Yellow perch	5	9.7	0.4	0.64	0.11	0.40	<0.05	0.04
	Yellow perch (R)	5	9.7	0.4	0.64	0.15	0.30	<0.05	0.05
52. Lake Champlain Burlington, Vt.	Pumpkinseed	5	7.8	0.5	0.32	0.15	0.31	<0.05	0.35
	Chain pickerel	5	17.1	1.1	0.50	0.05	0.50	<0.05	0.92
	Yellow perch	5	10.6	0.6	0.39	0.07	0.40	<0.05	0.29
	Yellow perch (R)	5	11.0	0.7	0.24	0.09	0.40	<0.05	0.38
53. Merrimac River Lowell, Mass.	White sucker	5	12.5	0.5	0.44	0.18	0.50	0.30	0.34
	Carp	5	10.2	0.5	0.09	0.14	0.80	<0.05	0.40
	Yellow perch	5	10.1	0.6	0.56	0.23	0.14	<0.05	0.30
	Yellow perch (R)	5	9.3	0.5	0.49	<0.05	<0.10	0.26	0.34
2. Connecticut River Windsor Locks, Conn.	White perch	5	10.0	0.5	0.32 (0.50)	0.10 (0.12)	0.34 (<0.20)	0.17 (0.08)	1.40 (1.17)
	Yellow perch	5	9.0	0.4	0.24	0.10	0.30	0.64	0.25
	White catfish	5	13.5	1.0	0.12 (0.20)	0.11 (0.10)	0.40 (0.07)	1.50 (0.16)	0.17 (0.20)
	White catfish (R)	5	13.3	1.0	0.15	0.20	0.40	0.56	0.17
3. Hudson River Poughkeepsie, N.Y.	Pumpkinseed	5	5.8	0.1	0.12	0.12	0.90	<0.05	0.37
	Largemouth bass	5	10.5	0.56	0.13	0.12	1.60	<0.05	0.37
	Goldfish	5	11.9	1.1	0.15	0.21	2.60	0.10	0.30
	Goldfish (R)	5	10.1	0.56	0.14	0.09	1.70	0.10	0.28
54. Raritan River Highland Park, N.J.	Golden shiner	5	7.3	0.2	0.14	0.09	1.10	<0.05	0.72
	Largemouth bass	5	9.7	0.5	0.28	0.12	<0.10	<0.05	0.58
	White perch	5	7.2	0.3	0.10	0.09	<0.10	<0.05	1.30
	White perch (R)	5	6.7	0.3	0.18	<0.05	1.40	<0.05	1.10
4. Delaware River Camden, N.J.	White sucker	5	15.0	1.5	0.18	0.18	0.72	<0.05	0.41
	Brown bullhead	5	11.5	0.9	0.02	0.10	1.30	<0.05	0.24
	White perch	5	11.1	0.5	0.10	0.09	0.56	<0.05	1.20
	White perch (R)	5	9.9	0.5	0.14	<0.05	0.46	<0.05	0.84
5. Susquehanna River Conowingo Dam, Md.	Carp	5	14.8	1.7	0.16	0.08	0.28	<0.05	0.55
	Channel catfish	5	13.1	0.8	0.10	0.18	0.28	<0.05	1.51
	Yellow perch	5	7.5	0.2	0.08	0.21	0.26	<0.05	0.46
	Yellow perch (R)	5	7.5	0.3	0.03	0.21	0.36	<0.05	0.80
6. Potomac River Little Falls, Md.	Carp	4	14.2	1.35	0.22	0.25	1.8	<0.05	0.20
	Redbreast sunfish	4	6.6	0.2	0.06	0.11	0.56	<0.05	0.52
	Smallmouth bass	1	16.2	1.9	0.36	<0.05	0.20	<0.05	0.40
	Redhorse[2]	5	13.3	2.2	0.16	0.07	<0.10	<0.05	0.24
	Redhorse (R)	5	13.2	1.0	0.24	<0.05	1.5	<0.05	0.24
55. James River Richmond, Va.	White sucker	3	16.2	2.0	0.08	0.12	<0.10	<0.05	0.92
	Redhorse	1	16.2	1.9	0.12	<0.05	<0.10	0.08	0.88
	River chub	5	11.5	0.7	0.05	0.17	0.14	<0.05	0.68
	River chub (R)	4	12.5	0.9	<0.05	0.2	<0.10	<0.05	0.48
7. Roanoke River Roanoke Rapids, N.C.	Largemouth bass	2	11.3	0.9	0.23	0.05	<0.10	<0.05	0.34
	White catfish	5	9.3	0.3	0.04	<0.05	0.30	<0.05	0.17
	Carp	4	19.4	3.5	0.11 (0.08)	0.16 (<0.05)	0.56 (<0.20)	0.06 (0.06)	0.60 (0.45)
	Bluegill	5	7.2	0.3	0.04	<0.05	<0.11	0.05	0.22
	Bluegill (R)	5	6.4	0.2	0.10	0.11	0.22	<0.05	0.19
8. Cape Fear River Elizabethtown, N.C.	Gizzard shad	3	9.6	0.5	0.10	0.21	0.22	<0.05	0.24
	Largemouth bass	4	11.0	0.8	0.40	0.14	<0.10	<0.05	0.12
	Brown bullhead	5	10.6	0.5	0.10	0.07	0.12	0.12	0.24
	Brown bullhead (R)	5	10.3	0.5	0.13	0.07	0.64	<0.05	0.32
56. Pee Dee River Dongola, S.C.	Brown bullhead	5	12.3	0.7	0.36	<0.05	<0.10	<0.05	0.26
	Largemouth bass	5	14.3	1.5	0.10	<0.05	1.2	0.55	0.23
	Bluegill	5	6.8	0.2	0.25	0.09	<0.10	<0.05	0.34
	Bluegill (R)	5	6.6	0.2	0.24	<0.05	<0.10	<0.05	0.54
9. Cooper River Summerton, S.C.	Carp	3	22.1	5.4	0.28	0.24	0.13	<0.05	0.52
	Largemouth bass	5	13.2	1.2	0.24	0.09	<0.10	<0.05	0.54
	Bluegill	5	6.9	0.2	0.01	<0.05	0.10	<0.05	0.23
	Bluegill (R)	5	6.3	0.2	0.12	<0.05	<0.10	<0.05	0.39

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TABLE 2 (cont'd.). *Concentrations of mercury, arsenic, lead, cadmium, and selenium in whole fish, 1972 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size: Length, in.	Average Size: Weight, lb	Residues, mg/kg wet weight: Mercury	Arsenic	Lead	Cadmium	Selenium
10. Savannah River Savannah, Ga.	Bluegill	5	7.1	0.3	0.14	0.15	0.10	<0.05	0.34
	Channel catfish	5	17.4	2.0	0.56	0.07	0.20	<0.05	0.09
	Largemouth bass	3	13.8	1.4	ND	ND	ND	ND	ND
					(1.25)	(0.10)	(<0.20)	(<0.05)	(0.45)
	Largemouth bass (R)	3	10.3	0.53	0.67	0.05	0.10	<0.05	0.16
57. Altamaha River Doctortown, Ga.	Bluegill	4	5.9	0.2	0.11	0.09	0.30	<0.05	0.16
	Largemouth bass	3	15.8	2.5	0.54	0.22	0.10	0.05	0.12
	Spotted sucker	4	17.5	2.1	0.26	<0.05	0.20	<0.05	0.43
	Spotted sucker (R)	4	15.5	1.5	0.32	0.05	0.20	<0.05	0.40
11. St. Johns River Welaka, Fla.	Striped mullet	5	17.1	2.1	0.03	0.12	0.32	<0.05	0.58
	Channel catfish	5	11.8	0.4	0.03	0.10	0.09	<0.05	0.26
	Largemouth bass	5	13.5	1.2	0.10	<0.05	0.12	<0.05	0.42
	Largemouth bass (R)	5	10.3	0.5	0.07	0.06	0.12	<0.05	0.36
12. St. Lucie Canal Indiantown, Fla.	Bluegill	5	6.1	0.2	0.09	0.09	<0.10	<0.05	0.60
	Largemouth bass	3	14.3	1.5	0.16	0.10	<0.10	<0.05	0.62
	White catfish	5	13.5	1.4	0.06	<0.05	0.17	<0.05	0.42
	White catfish (R)	5	11.6	0.8	0.06	0.17	<0.10	<0.05	0.45
Gulf Coast Streams									
58. Suwanee River Old Town, Fla.	Redbreast sunfish	5	5.9	0.1	0.09	0.08	<0.10	<0.05	0.44
	Largemouth bass	5	11.5	0.7	0.49	0.09	<0.10	<0.05	0.72
	Spotted sucker	5	16.8	1.8	0.11	0.15	<0.10	<0.05	0.76
	Spotted sucker (R)	5	14.1	1.2	0.07	0.06	<0.10	<0.05	0.44
13. Apalachicola River Jim Woodruff Dam, Ala.	Spotted sucker	3	19.0	2.9	0.09	0.10	<0.10	<0.05	0.56
	Largemouth bass	3	14.1	1.4	0.19	0.06	<0.10	<0.05	0.40
	Carp	3	22.6	6.9	0.07	0.10	<0.10	<0.05	0.52
	Carp (R)	3	25.7	9.0	0.05	0.23	<0.10	<0.05	0.40
59. Alabama River Chrysler, Ala.	Striped mullet	1	12.3	0.7	0.04	0.29	<0.10	<0.05	0.28
	Freshwater drum	3	9.1	0.2	0.08	0.05	<0.10	<0.05	0.44
	Channel catfish	3	11.8	0.4	0.04	0.05	<0.10	0.16	0.41
	Largemouth bass	3	14.1	1.3	0.16	0.05	<0.10	<0.05	0.64
	Largemouth bass (R)	3	13.1	1.3	0.36	0.09	<0.10	<0.05	0.10
14. Tombigbee River McIntosh, Ala.	Striped mullet	5	15.6	1.4	0.10	0.28	0.19	<0.05	0.72
	Largemouth bass	5	10.6	0.7	0.96	0.05	<0.10	<0.05	0.40
	Channel catfish	5	13.7	0.7	0.12	0.21	<0.10	<0.05	0.40
					(0.08)	(0.08)	(<0.20)	(<0.05)	(0.29)
	Channel catfish (R)	5	12.7	0.5	0.13	0.14	0.10	<0.05	0.56
15. Mississippi River Luling, La.	Carp	3	23.0	6.1	0.08	0.14	0.18	<0.05	0.52
	Channel catfish	5	13.8	1.1	0.06	0.20	0.30	<0.05	1.30
	Freshwater drum	5	14.2	1.4	0.14	0.13	0.16	0.12	1.44
	Freshwater drum (R)	5	9.8	0.7	0.16	0.08	0.16	0.28	0.64
60. Brazos River Richmond, Tex.	Longnose gar	3	25.4	0.87	0.17	0.08	0.40	<0.05	0.40
	River carpsucker	3	10.4	0.58	0.06	0.25	1.1	0.11	0.32
	Channel catfish	3	12.4	0.56	0.10	0.09	1.20	0.07	0.40
	Blue catfish	3	13.9	1.1	0.12	0.06	0.60	<0.05	0.20
61. Colorado River Wharton, Tex.	Spotted gar	3	20.5	1.3	0.46	<0.05	0.22	<0.05	0.28
	Channel catfish	3	16.7	1.5	0.12	0.06	0.70	0.17	0.36
	River carpsucker	3	13.2	1.0	0.14	0.28	3.6	<0.05	0.40
	River carpsucker (R)	3	13.2	1.21	0.11	0.13	2.9	<0.05	0.30
62. Nueces River Mathis, Tex.	Channel catfish	5	10.4	0.3	0.02	<0.05	<0.10	<0.05	0.20
	Blue catfish	5	12.8	0.8	0.06	0.05	<0.10	<0.05	0.18
	Gizzard shad	5	12.1	0.7	0.02	<0.05	<0.10	<0.05	0.49
	Gizzard shad (R)	5	11.6	0.6	0.02	0.08	0.26	<0.05	1.10
16. Rio Grande Brownsville, Tex.	Channel catfish	3	15.2	1.1	0.11	<0.05	0.10	<0.05	0.41
	Blue catfish	4	14.3	1.2	0.08	<0.05	0.22	<0.05	0.70
	Gizzard shad	5	8.0	0.2	0.02	0.18	<0.10	<0.05	0.71
	Gizzard shad (R)	5	6.9	0.1	0.01	<0.05	<0.10	<0.05	0.51
63. Rio Grande Elephant Butte, N. Mex.	Largemouth bass	5	15.0	2.0	0.28	0.27	<0.10	<0.05	0.66
					(0.35)	(0.28)	(<0.20)	(<0.05)	(0.49
	Carp	5	12.3	1.0	0.16	0.13	0.17	<0.05	0.64
	Channel catfish	5	10.2	0.56	0.24	0.08	<0.10	<0.05	0.20
	Channel catfish (R)	5	8.9	0.3	0.16	0.08	0.18	<0.05	0.23
					(0.21)	(<0.05)	(<0.20)	(<0.05)	(0.34)
64. Rio Grande Alamosa, Colo.	Brown trout	5	13.3	0.9	0.10	0.23	0.14	<0.05	0.23
	Carp	5	15.4	2.1	0.05	0.08	4.65	<0.05	0.38
	White sucker	5	11.3	0.6	0.06	0.14	1.4	<0.05	0.23
	White sucker (R)	5	15.1	1.3	0.14	0.05	0.60	<0.05	0.27

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TABLE 2 (cont'd.). *Concentrations of mercury, arsenic, lead, cadmium, and selenium in whole fish, 1972 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size: Length, in.	Average Size: Weight, lb	Residues, mg/kg wet weight: Mercury	Arsenic	Lead	Cadmium	Selenium
65. Pecos River Red Bluff Lake, Tex.	Gizzard shad	5	10.4	0.4	0.01	0.05	0.10	<0.10	0.48
	Channel catfish	5	14.4	0.9	0.09	<0.05	<0.10	0.05	0.24
	Smallmouth buffalo	5	13.6	1.1	0.08	0.05	0.10	0.09	1.00
	Smallmouth buffalo (R)	5	13.7	1.1	0.10	0.12	0.10	0.05	0.28
Great Lakes Drainage									
17. Genessee River Scottsville, N.Y.	Rock bass	5	7.4	0.4	0.07	0.10	0.16	<0.05	0.70
	Redhorse	5	15.4	1.5	0.07	0.09	0.34	<0.05	0.34
	Northern pike	5	20.7	2.1	0.11	0.13	<0.10	<0.05	0.31
66. St. Lawrence River Massena, N.Y.	White sucker	4	13.6	1.2	0.08	0.09	<0.10	<0.05	0.46
	Northern pike	5	24.7	3.5	0.24	0.08	0.22	<0.05	0.58
	Yellow perch	5	8.8	0.3	0.12	0.09	0.90	<0.05	0.48
	Yellow perch (R)	5	8.7	0.3	0.12	0.09	1.30	<0.05	0.38
	Northern pike	5	19.6	1.8	0.07	<0.05	<0.10	<0.05	0.34
18. Lake Ontario Port Ontario, N.Y.	White perch	5	8.2	0.4	0.31 (0.15)	0.08 (0.25)	1.1 (<0.2)	<0.05 (<0.05)	1.40 (1.00)
	Rock bass	5	7.7	0.4	0.25	0.21	0.60	<0.05	0.80
	Yellow perch	5	9.1	0.4	0.47	0.12	2.2	<0.05	0.52
	Yellow perch (R)	5	9.2	0.4	0.24	0.20	1.0	<0.05	0.60
19. Lake Erie Erie, Pa.	White sucker	4	12.6	1.2	0.16	0.12	0.16	<0.05	0.58
	Freshwater drum	5	13.5	1.1	0.16	0.07	0.18	<0.05	0.84
	Yellow perch	5	8.6	0.3	0.16	<0.05	0.20	<0.05	0.80
	Yellow perch (R)	5	9.0	0.4	0.04 (0.08)	0.09 (0.08)	0.16 (<0.20)	<0.05 (<0.05)	0.64 (0.62)
20. Lake Huron Bay Port, Mich.	Yellow perch	5	8.6	0.26	0.07	0.06	<0.10	0.01	0.23
	Yellow perch (R)	5	8.5	0.28	<0.05	0.09	<0.10	0.01	0.19
21. Lake Michigan Sheboygan, Wis.	Bloater	5	10.7	0.50	0.16	0.65	0.12	<0.05	0.34
	Bloater (R)	5	10.9	0.62	0.12 (0.11)	1.70 (2.40)	0.12 (<0.20)	<0.05 (<0.05)	0.48 (0.31)
	Yellow perch	5	11.0	0.85	0.26	0.07	<0.10	<0.05	1.00
	Yellow perch (R)	5	10.7	0.82	0.26	0.07	0.12	<0.05	0.82
	Lake trout	5	18.3	2.5	0.20 (0.18)	0.36 (0.69)	<0.10 (<0.20)	<0.05 (<0.05)	0.48 (0.51)
	Lake trout (R)	5	19.2	2.5	0.20	0.15	<0.10	<0.05	0.74
22. Lake Superior Bayfield, Wis.	Bloater	5	10.1	0.27	0.20 (0.17)	0.17 (0.50)	0.18 (0.50)	0.08 (0.08)	0.49 (0.40)
	Bloater (R)	5	10.0	0.28	0.10	0.42	0.10	0.08	0.32
	Lake whitefish	5	21.2	3.2	0.08	0.40	0.20	<0.05	0.38
	Lake trout	5	22.9	3.7	0.26	0.13	<0.10	<0.05	0.24
	Lake trout (R)	5	20.9	3.2	0.28	0.21	<0.10	<0.05	0.52
Mississippi River System									
67. Allegheny River Natrona, Pa.	Carp	5	17.8	2.9	0.09	0.17	0.66	0.11	0.52
	Walleye	5	15.6	1.0	0.04	0.07	0.20	<0.05	0.49
	Smallmouth bass	5	9.9	0.4	0.08	<0.05	0.24	<0.05	0.70
	Smallmouth bass (R)	5	11.0	0.7	0.08	<0.05	0.22	<0.05	0.60
23. Kanawha River Winfield, W. Va.	Carp	3	10.1	1.4	0.01	0.13	2.0	<0.05	0.80
	White crappie	5	7.5	0.2	0.06	0.07	0.28	<0.05	0.72
	Brown bullhead	5	10.4	0.5	0.01	<0.05	2.4	<0.05	0.38
	Brown bullhead (R)	5	10.9	0.5	0.03	0.07	2.9	<0.05	0.22
68. Wabash River New Harmony, Ind.	Carp	5	17.4	2.8	0.16	0.15	<0.10	1.40	0.40
	Channel catfish	5	11.3	0.3	0.07	<0.05	0.15	<0.05	0.38
	White sucker	5	9.3	0.4	0.14	<0.05	6.40	<0.05	0.38
	White sucker (R)	5	8.0	0.4	0.12	0.07	0.31	<0.05	0.56
24. Ohio River Marietta, Ohio	Carp	5	13.1	1.2	0.18	0.25	1.3	0.09	0.72
	Redhorse sucker	5	10.4	0.8	0.04	0.11	0.90	<0.05	0.14
	Channel catfish	5	14.6	0.9	0.18	0.06	0.60	<0.05	0.34
	Channel catfish (R)	5	14.3	0.8	0.46	<0.05	0.70	<0.05	0.29
69. Ohio River Cincinnati, Ohio	Carp	5	14.8	1.6	0.06	0.20	0.20	0.48	0.68
	Channel catfish	5	14.9	1.1	0.12	0.10	0.30	0.76	0.68
	Sauger	5	11.7	0.54	0.10 (0.13)	0.19 (0.11)	<0.10 (<0.20)	<0.05 (<0.05)	0.44 (0.43)
	Sauger (R)	5	12.8	0.9	0.24	0.17	<0.10	0.05	0.40
70. Ohio River Metropolis, Ill.	Carp	5	17.7	3.0	0.21	0.15	0.18	0.08	0.64
	Channel catfish	5	ND	ND	0.09	0.13	0.16	<0.05	0.34
	White crappie	5	11.4	0.9	0.09	0.19	<0.10	<0.05	0.34
	White crappie (R)	5	11.2	0.9	0.16	0.15	<0.10	<0.05	0.30

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TABLE 2 (cont'd.). *Concentrations of mercury, arsenic, lead, cadmium, and selenium in whole fish, 1972 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size: Length, in.	Average Size: Weight, lb	Residues, mg/kg wet weight: Mercury	Arsenic	Lead	Cadmium	Selenium
25. Cumberland River Clarksville, Tenn.	Carp	5	16.3	1.9	0.04 (0.37)	<0.05 (0.16)	0.34 (<0.20)	0.05 (<0.05)	0.55 (0.54)
	Largemouth bass	5	13.4	1.6	0.34	0.10	<0.10	<0.05	0.36
	Bluegill	5	6.5	0.1	0.12	0.06	0.13	<0.05	0.38
	Bluegill (R)	5	6.2	0.1	0.19	0.05	<0.10	<0.05	1.10
71. Tennessee River Savannah, Tenn.	Largemouth bass	3	9.5	0.3	0.22	<0.05	<0.10	<0.05	0.44
	White sucker	3	15.0	1.4	0.78	0.06	0.10	<0.05	0.70
	Carp	3	19.3	3.7	0.28	0.17	0.50	0.12	0.68
	Carp (R)	3	18.4	2.7	0.28	0.24	0.18	0.09	0.56
72. Wisconsin River Woodman, Wis.	Smallmouth buffalo	4	15.6	2.3	0.11	0.14	0.22	<0.05	0.31
	Mooneye	3	10.3	0.4	0.01	0.10	<0.10	<0.05	0.52
	White sucker	5	15.2	1.5	0.15 (0.13)	0.17 (0.06)	0.18 (<0.20)	<0.05 (<0.05)	0.64 (0.58)
	White sucker (R)	4	13.0	1.2	0.02	0.14	<0.10	<0.05	0.24
73. Des Moines River Keosauqua, Iowa	Largemouth bass	5	13.1	1.2	0.16	0.07	0.80	<0.05	0.76
	Walleye	1	14.7	1.3	0.09	0.24	0.60	0.05	0.96
	Channel catfish	4	14.3	0.7	0.09	<0.05	0.16	<0.05	0.54
	Carp	5	15.2	1.6	0.03	0.09	0.60	0.07	1.10
	Carp (R)	5	13.2	1.0	0.03	0.09	0.16	<0.05	1.00
26. Illinois River Beardstown, Ill.	Carp	5	14.2	1.3	0.06	<0.05	0.34	0.07	1.20
	Smallmouth buffalo	4	13.2	1.2	0.04	0.13	0.14	<0.05	0.76
	White crappie	3	10.1	0.6	0.04	0.16	<0.10	<0.05	0.72
	White crappie (R)	4	9.6	0.5	0.04	0.23	<0.10	0.20	0.38
74. Mississippi River Little Falls, Minn.	Northern pike	3	25.9	3.9	0.20	0.18	0.22	<0.05	0.52
	Yellow bullhead	3	11.5	2.1	0.46	0.20	<0.10	<0.05	0.68
	White sucker	5	18.7	3.1	0.09	0.18	<0.10	<0.05	0.20
	White sucker (R)	5	18.5	2.9	0.09	0.17	<0.10	<0.05	ND
27. Mississippi River Guttenburg, Iowa	Carp	5	16.5	2.2	0.12	<0.05	<0.10	<0.05	0.18
	Bluegill	5	7.3	0.3	0.18	<0.05	0.14	<0.05	0.69
	Largemouth bass	5	11.6	0.9	0.08	0.07	0.36	<0.05	0.23
	Largemouth bass (R)	5	11.2	0.8	0.08	0.05	<0.10	<0.05	0.39
75. Mississippi River Cape Girardeau, Mo.	Blue catfish	4	14.1	1.4	0.07	<0.05	<0.10	<0.05	0.38
	White crappie	5	10.7	0.6	0.10	0.34	<0.10	0.26	0.44
	Carp	5	14.4	1.5	0.06	<0.05	0.10	0.20	0.38
	Carp (R)	5	14.3	1.3	0.06	<0.05	0.10	0.09	0.87
76. Mississippi River Memphis, Tenn.	Freshwater drum	4	12.2	0.7	0.20	0.11	0.80	0.80	0.48
	Channel catfish	4	15.2	1.1	0.06	<0.05	<0.70	<0.05	0.50
	Carp	3	70.2	0.4	0.05	<0.05	0.40	0.36	0.80
	Carp (R)	3	21.1	4.1	0.11	0.16	0.30	0.09	0.70
28. Arkansas River Pine Bluff, Ark.	Carp	3	20.8	5.6	0.16	0.33	0.32	0.06	0.24
	Smallmouth buffalo	3	19.4	5.1	0.14	0.31	0.31	0.06	0.44
	Channel catfish	4	18.9	2.7	0.14	0.31	0.31	<0.05	ND
	Channel catfish (R)	4	10.5	0.2	0.06	0.06	2.0	<0.05	0.32
29. Arkansas River Keystone Reservoir, Okla.	Bluegill	5	6.3	0.3	<0.05	0.10	<0.10	<0.05	1.10
	Largemouth bass	4	15.5	2.3	0.08	0.25	0.38	<0.05	1.10
	Carp	5	11.7	0.8	0.05 (0.09)	0.40 (0.12)	0.10 (0.20)	0.09 (<0.05)	0.68 (0.51)
	Carp (R)	5	13.3	1.1	0.08	<0.05	0.20	0.48	0.44
77. Arkansas River John Martin Reservoir, Colo.	Carp	5	15.0	1.8	0.04	<0.05	0.13	<0.05	6.60
	Carp (R)	5	12.5	1.0	<0.05	<0.05	<0.10	<0.05	4.60
78. Verdigris River Oologah, Okla.	Carp	3	17.8	3.0	0.06 (0.09)	0.08 (0.10	0.13 (<2.20)	<0.05 (<0.05)	0.92 (0.65)
	Largemouth bass	4	13.6	1.5	0.15	0.27	<0.10	<0.05	0.60
	Bluegill	5	6.1	0.2	0.06	0.06	0.38	<0.05	1.00
	Bluegill (R)	5	5.1	0.1	0.10	<0.05	0.18	<0.05	1.20
79. Canadian River Eufaula, Okla.	No samples collected								
30. White River De Valls Bluff, Ark.	Carp	3	18.5	3.4	0.14	0.08	0.80	0.05	0.28
	Bigmouth buffalo	2	19.5	4.7	0.27	0.26	0.22	0.06	0.36
	Smallmouth buffalo	3	18.1	2.8	0.16	0.28	0.80	<0.05	0.40
	Smallmouth buffalo (R)	3	16.6	2.3	0.11	0.19	0.80	<0.05	0.28
80. Yazoo River Redwood, Miss.	Freshwater drum	1	16.8	2.6	0.11	0.16	0.12	<0.05	0.80
	Carp	4	22.1	5.1	0.16	<0.05	0.10	1.30	1.00
	Smallmouth buffalo	3	19.5	4.7	0.27	0.09	0.10	0.46	0.64
	Smallmouth buffalo (R)	3	16.7	2.9	0.15	0.11	0.10	0.05	0.44

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TABLE 2 (cont'd.). *Concentrations of mercury, arsenic, lead, cadmium, and selenium in whole fish, 1972 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size: Length, in.	Average Size: Weight, lb	Residues, mg/kg wet weight: Mercury	Arsenic	Lead	Cadmium	Selenium
81. Red River Alexandria, La.	Smallmouth buffalo	3	18.2	3.6	0.18	<0.05	0.28	<0.05	0.52
	Channel catfish	4	13.7	0.9	0.14	0.16	0.40	0.05	0.36
	Freshwater drum	4	13.8	1.3	0.08	0.11	0.14	<0.05	0.64
	Freshwater drum (R)	3	13.7	1.2	0.18	0.13	0.14	<0.05	0.84
82. Red River Lake Texoma, Okla.	Bluegill	5	7.4	0.3	0.05	0.12	0.06	<0.05	0.13
	Largemouth bass	5	16.2	2.2	0.12	0.22	0.18	<0.05	0.62
	Carp	5	15.1	1.3	<0.01	0.25	0.10	<0.05	0.54
					(<0.05)	(0.12)	(0.20)	(<0.05)	(0.44)
	Carp (R)	5	15.9	1.7	<0.05	0.20	0.10	<0.05	0.58
83. Missouri River Hermann, Mo.	Smallmouth buffalo	4	16.8	2.7	0.06	0.11	0.60	<0.05	1.20
	Channel catfish	5	18.4	2.1	0.04	0.07	<0.10	<0.05	0.18
	Blue catfish	4	14.7	1.0	0.13	0.11	<0.10	<0.05	0.14
	Carp	4	20.3	4.0	0.07	0.08	0.5	<0.05	0.90
	Carp (R)	4	19.2	3.4	0.09	<0.05	0.5	<0.05	1.00
31. Missouri River Nebraska City, Nebr.	Channel catfish	3	15.0	1.1	<0.05	0.13	0.32	<0.05	0.76
	Goldeye	5	13.6	0.9	0.14	0.13	0.78	<0.05	1.20
	Carp	5	17.9	2.9	<0.05	<0.05	0.28	<0.05	0.76
	Carp (R)	5	16.6	2.2	0.20	<0.05	0.30	0.07	1.30
32. Missouri River Garrison Dam, N. Dak.	Carp	3	18.1	2.6	0.02	0.20	1.3	0.36	0.38
	Walleye	5	16.9	1.6	0.13	0.15	1.1	0.12	0.80
	Goldeye	5	12.5	0.8	0.18	0.28	0.50	0.12	0.57
	Goldeye (R)	5	13.0	0.8	0.12	0.21	4.2	0.85	0.54
33. Missouri River Great Falls, Mont.	Sauger	3	17.1	2.0	0.50	<0.05	<0.10	<0.05	0.54
	Redhorse	4	16.5	1.9	0.24	0.07	0.30	0.32	0.38
	Goldeye	5	12.7	0.6	0.11	0.09	0.11	<0.05	1.10
	Goldeye (R)	5	12.3	0.6	0.10	0.16	<0.10	<0.05	1.20
84. Big Horn River Hardin, Mont.	Carp	5	17.2	2.7	0.04	<0.05	<0.10	0.07	3.20
	Goldeye	2	12.5	0.6	0.16	<0.05	<0.10	<0.05	2.30
	Goldeye (R)	5	12.5	0.7	0.13	<0.05	<0.10	<0.05	3.50
85. Yellowstone River Sidney, Mont.	Sauger	1	10.5	0.4	0.13	0.11	0.20	<0.05	0.61
	Carp	3	15.6	2.1	0.05	<0.05	0.20	0.30	0.68
	Goldeye	5	12.3	0.7	0.17	0.10	0.32	<0.05	0.80
	Goldeye (R)	5	11.6	0.6	0.13	0.09	0.26	<0.05	1.20
86. James River Olivet, S. Dak.	Carp	4	17.4	2.5	0.12	0.10	0.10	<0.05	0.35
	Channel catfish	5	16.4	1.7	0.10	<0.05	0.20	<0.05	0.35
	Goldeye	5	15.7	1.0	0.22	0.23	0.50	<0.05	0.88
	Goldeye (R)	5	13.7	1.2	0.19	<0.05	0.10	<0.05	0.64
87. North Platte River Lake McConaughy, Nebr.	Walleye	5	15.6	1.5	0.21	0.09	<0.10	<0.05	1.10
	Channel catfish	5	16.6	1.6	0.23	<0.05	0.13	<0.05	0.76
	Carp	5	18.1	2.9	0.16	0.10	0.24	0.05	1.20
	Carp (R)	5	18.8	3.1	0.23	<0.05	0.22	0.05	1.40
88. South Platte River Brule, Nebr.	Green sunfish	5	5.2	0.1	0.21	<0.05	0.10	<0.05	1.10
	White sucker	5	10.6	0.5	0.11	<0.05	0.20	<0.05	1.20
	Carp	5	17.0	2.4	0.34	<0.05	0.28	0.06	1.20
	Carp (R)	5	17.3	2.4	0.26	0.05	0.16	0.07	1.40
89. Platte River Louisville, Nebr.	White crappie	5	5.5	0.4	0.12	0.06	<0.10	<0.05	1.20
	Channel catfish	5	15.4	1.2	0.20	0.06	0.20	<0.05	0.72
	Carp	5	15.4	1.7	0.12	0.09	0.20	<0.05	1.10
	Carp (R)	5	16.3	2.0	0.11	0.12	0.30	<0.05	1.20
90. Kansas River Bonner Springs, Kans.	Carp	5	20.5	4.1	0.02	0.12	0.60	<0.05	0.96
	Gizzard shad	5	11.3	0.5	0.07	0.07	1.4	<0.05	1.30
	Gizzard shad (R)	5	9.7	0.3	0.05	0.09	0.70	<0.05	0.27
Hudson Bay Drainage									
34. Red River Noyes, Minn.	Channel catfish	3	19.3	2.9	0.32	0.11	0.14	0.05	0.31
	Redhorse	4	17.6	1.9	0.49	0.11	<0.10	0.06	0.66
	Sauger	5	14.8	0.9	0.56	<0.05	<0.10	<0.05	0.36
	Sauger (R)	5	12.2	0.36	0.75	<0.05	0.40	<0.05	0.46
Colorado River System									
35. Green River Vernal, Utah	Carp	3	15.3	2.1	0.08	0.05	0.26	<0.05	1.20
	Channel catfish	5	10.8	0.3	0.20	<0.05	<0.10	<0.05	0.92
	Flannelmouth sucker	4	12.7	1.5	0.03	0.27	0.26	<0.05	0.76
	Flannelmouth sucker (R)	3	17.5	1.9	0.20	0.25	<0.10	<0.05	0.60
36. Colorado River Imperial Reservoir, Ariz.	Largemouth bass	4	9.6	0.5	<0.01	0.09	<0.10	<0.05	3.60
	Bluegill	5	6.1	0.2	0.01	<0.10	0.10	<0.05	2.60
	Carp	3	17.9	3.0	0.01	0.06	0.26	<0.05	3.20
	Carp (R)	3	17.7	2.9	0.01	0.10	0.16	<0.05	3.00

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TABLE 2 (cont'd.). *Concentrations of mercury, arsenic, lead, cadmium, and selenium in whole fish, 1972 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size: Length, in.	Average Size: Weight, lb	Residues, mg/kg wet weight: Mercury	Arsenic	Lead	Cadmium	Selenium
91. Colorado River Lake Havasu, Ariz.	Largemouth bass	4	11.4	1.0	0.08	0.27	0.10	<0.05	1.40
	Yellow bullhead	5	8.9	0.4	0.05	<0.05	<0.10	<0.05	3.10
	Carp	5	12.5	1.0	<0.05	0.10	0.46	<0.05	3.20
	Carp (R)	4	13.9	1.5	0.05	0.15	0.22	<0.05	3.60
92. Colorado River Lake Mead, Nev.	Carp	5	15.4	1.6	0.03	0.14	2.1	<0.05	2.00
	Largemouth bass	5	12.4	1.0	0.04	0.17	0.17	0.05	3.00
	Channel catfish	5	14.6	0.7	0.01	0.16	1.7	0.05	2.50
	Channel catfish (R)	5	14.5	0.6	0.05	ND	ND	ND	ND
93. Colorado River Lake Powell, Ariz.	Rainbow trout	5	17.4	2.2	0.27	0.13	<0.10	<0.05	3.00
	Largemouth bass	5	15.5	2.3	0.49	<0.05	<0.10	<0.05	2.20
	Carp	5	14.2	1.1	0.14 (0.15)	<0.05 (0.13)	0.20 (0.50)	0.10 (0.15)	1.70 (1.22)
	Carp (R)	5	13.4	0.9	0.14	<0.05	0.20	0.22	2.20
94. Gila River San Carlos Reservoir, Ariz.	Largemouth bass	3	14.8	2.1	0.41	0.19	<0.10	<0.05	0.48
	Channel catfish	3	13.5	0.7	0.10	0.08	<0.10	<0.05	0.52
	Carp	3	13.0	0.9	0.30	0.09	1.0	0.14	0.36
	Carp (R)	4	11.9	0.7	0.18 (0.14)	0.10 (0.16)	0.50 (<0.20)	0.09	0.36 0.47
Interior Basins									
37. Truckee River Fernley, Nev.	Brown bullhead	2	8.9	0.82	0.39	0.09	0.24	<0.05	0.10
	Largemouth bass	5	12.7	1.2	<0.05	0.26	<0.10	<0.05	0.20
	Carp	5	17.3	2.4	0.50	0.15	0.24	<0.05	0.31
	Carp (R)	5	13.3	1.2	0.21	<0.10	0.10	<0.05	0.29
38. Utah Lake Provo, Utah	Carp	5	17.1	1.9	0.02	ND	0.02	<0.05	0.39
	White bass	5	10.3	0.4	0.01	0.20	0.18	<0.05	0.84
	Black bullhead	5	9.7	0.5	0.01	<0.05	<0.10	<0.05	0.29
	Black bullhead (R)	5	10.7	0.8	0.01	0.08	<0.10	<0.05	0.29
95. Bear River Preston, Idaho	Carp	3	17.6	4.1	0.14	<0.05	<0.10	<0.05	0.24
	Largescale sucker	5	15.1	1.6	0.08	0.16	<0.10	<0.05	0.16
	Yellow perch	5	5.2	0.1	0.06	<0.05	<0.10	<0.05	0.40
	Yellow perch (R)	5	6.0	0.1	0.14	<0.05	<0.10	<0.05	0.30
California Streams									
39. Sacramento River Sacramento, Calif.	White catfish	5	10.2	0.5	0.02	0.17	0.10	0.60	0.28
	Largemouth bass	5	11.3	0.9	0.32	0.17	<0.10	0.88	0.24
	Carp	5	11.6	1.0	0.03	<0.05	<0.10	0.80	0.36
	Carp (R)	5	11.5	1.0	0.24	0.06	0.10	1.00	0.28
40. San Joaquin Los Banos, Calif.	Black crappie	5	11.0	0.9	0.04	<0.05	<0.10	0.13	0.31
	Sacramento blackfish	5	11.4	0.8	0.05	0.10	<0.10	0.16	0.30
	Carp	5	11.6	1.0	0.04 (0.05)	<0.05 (<0.05)	<0.10 (<0.20)	<0.05 (<0.05)	0.37 (0.59)
	Carp (R)	5	12.0	1.2	0.03	<0.05	<0.10	<0.05	0.35
Columbia River System									
43. Salmon River Riggins, Idaho	Northern squawfish	5	9.3	0.3	0.18	0.07	<0.10	<0.05	0.27
	Smallmouth bass	5	9.6	0.6	0.21 (0.46)	<0.05 (0.07)	<0.10 (<0.20)	<0.05 (<0.05)	0.68 (0.84)
	Largescale sucker	4	14.5	1.3	0.08	0.08	0.10	0.09	0.20
	Largescale sucker (R)	4	13.7	1.2	0.16	0.20	0.20	0.36	0.25
41. Snake River Hagerman, Idaho	Northern squawfish	4	10.6	0.6	0.02	0.14	0.22	<0.05	0.19
	Peamouth chub	5	9.2	0.3	0.26	0.80	0.10	<0.05	0.84
	Largescale sucker	5	11.3	0.7	0.21 (0.11)	<0.05 (0.09)	0.10 (<0.20)	0.13 (<0.05)	0.25 (1.11)
	Largescale sucker (R)	5	12.1	0.9	0.06	0.05	<0.10	<0.05	0.17
42. Snake River Lewiston, Idaho	Carp	3	17.1	3.1	0.17	0.14	<0.10	0.88	0.17
	Northern squawfish	5	15.4	1.6	0.08	0.12	<0.10	<0.05	0.14
	Largescale sucker	5	14.1	1.2	0.01	0.15	0.10	0.09	0.29
	Largescale sucker (R)	5	15.0	1.4	0.03	0.18	0.10	0.26	0.20
96. Snake River Ice Harbor, Wash.	Largescale sucker	5	13.5	1.0	0.18	0.17	0.20	0.05	0.17
	Channel catfish	5	12.5	0.9	0.14	0.25	<0.10	0.05	0.07
	Northern squawfish	5	8.7	0.3	0.03	0.31	<0.10	<0.05	0.27
	Northern squawfish (R)	4	8.5	0.3	0.04	0.14	<0.10	<0.05	0.15
44. Yakima River Granger, Wash.	Carp	5	10.5	0.8	0.24	0.20	<0.10	0.42	0.40
	Northern squawfish	5	10.8	0.5	0.64	0.10	<0.10	0.05	0.40
	Largescale sucker	5	14.6	1.1	0.03	0.20	<0.10	<0.05	0.24
	Largescale sucker (R)	5	14.0	1.0	0.23	0.16	<0.10	<0.05	0.16

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TABLE 2 (cont'd.). *Concentrations of mercury, arsenic, lead, cadmium, and selenium in whole fish, 1972 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size: Length, in.	Average Size: Weight, lb	Residues, mg/kg wet weight: Mercury	Arsenic	Lead	Cadmium	Selenium
45. Willamette River Oregon City, Oreg.	Channel catfish	5	13.7	1.0	0.29	<0.05	0.10	<0.05	0.06
	Northern squawfish	5	14.3	1.2	0.04	<0.05	0.20	0.13	0.04
	Largescale sucker	5	14.6	1.4	0.24	0.14	0.10	<0.05	0.12
	Largescale sucker (R)	5	14.8	1.3	0.04	<0.05	0.10	0.02	0.09
46. Columbia River Bonneville Dam, Oreg.	Carp	5	11.9	1.0	0.08	0.15	0.58	0.16	0.31
	Largescale sucker	3	16.0	1.7	0.23	<0.05	0.10	0.16	0.14
	Northern squawfish	5	13.5	1.0	0.06	0.11	0.30	0.42	0.11
	Carp	5	12.2	1.0	0.12	0.12	0.20	1.80	0.40
97. Columbia River Pasco, Wash.	Northern squawfish	5	13.5	1.0	0.06	0.11	0.30	0.42	0.11
	Carp	5	12.2	1.0	0.12	0.12	0.20	1.80	0.40
	Largescale sucker	5	14.7	1.2	0.05	0.29	0.30	0.60	0.28
	Largescale sucker (R)	5	14.7	1.2	0.05	0.16	0.20	0.54	0.28
98. Columbia River Grand Coulee, Wash.	Bridgelip sucker	5	15.3	1.4	0.02	0.18	0.90	0.28	0.24
	Northern squawfish	5	15.0	1.1	0.47	0.13	0.30	1.70	0.23
	Walleye	5	14.9	1.0	0.11	0.22	<0.10	0.16	0.34
	Walleye (R)	5	14.2	0.8	0.12	0.05	<0.10	0.16	0.30
Pacific Coast Streams									
47. Klamath River Hornbrook, Calif.	No samples collected								
48. Rogue River Gold Ray Dam, Oreg.	Carp	5	12.8	1.4	0.12	0.13	0.10	<0.05	0.15
	Brown bullhead	5	10.6	0.6	0.04	0.06	0.20	<0.05	0.10
	Brown bullhead (R)	5	10.4	0.6	0.18	<0.05	0.16	<0.05	0.15
Alaskan Streams									
49. Chena River Fairbanks, Alaska	Round whitefish	3	9.7	0.5	0.06	0.08	0.10	0.05	1.20
	Arctic grayling	4	10.9	0.7	0.08	<0.05	0.20	0.20	1.30
	Longnose sucker	3	16.2	2.0	0.03	0.07	0.10	0.26	0.33
	Longnose sucker (R)	3	15.5	1.8	0.14	0.17	0.10	0.09	0.34
50. Kenai River Soldatna, Alaska	Rainbow trout	3	9.8	0.4	0.01	<0.05	<0.10	<0.05	0.88
	Round whitefish	5	12.0	0.5	0.03	0.13	1.2	0.07	ND
	Lake trout	5	14.0	0.9	0.01	0.15	0.31	<0.05	0.60
	Lake trout (R)	5	14.6	1.0	0.18	0.16	0.40	<0.05	ND
Hawaiian Streams									
99. Waikele Stream Waipahu, Hawaii	Tilapia	3	5.0	0.1	0.02	<0.05	4.8	0.08	1.40
	Chinese catfish	3	8.5	0.16	0.22	<0.05	1.70	0.07	1.00
	Chinese catfish (R)	3	8.3	0.15	0.46	0.11	4.60	0.07	1.30
	Cuban limia	8	3.4	ND	0.05	0.12	2.0	<0.05	0.38
100. Manoa Stream Honolulu, Hawaii	Tilapia	5	6.3	0.26	0.04	0.10	4.2	0.14	0.51
	Chinese catfish	4	8.6	0.20	0.08	0.12	4.2	<0.05	0.35
	Chinese catfish (R)	3	9.2	0.25	0.10	<0.05	5.2	0.07	0.28
	Cuban limia	18	3.2	ND	0.03	0.20	1.4	<0.05	0.42

NOTE: R = replicate sample.
ND = not detected.
Numbers in parentheses are results of cross-check analyses.
[1] Redhorse = *Moxostoma* sp.

TABLE 3. *Concentrations of mercury, arsenic, lead, and cadmium in selected fish and selenium residues in all fish, 1973 —National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size: Length, in.	Average Size: Weight, lb	Residues, mg/kg wet weight: Mercury	Arsenic	Lead	Cadmium	Selenium
Atlantic Coast Streams									
1. Stillwater River Old Town, Maine	Yellow perch	5	8.8	0.3	0.44 (0.30)	—	—	—	0.19
	White sucker	5	14.8	1.3	0.39	—	—	—	0.14
	White sucker (R)	5	13.6	1.0	0.34	—	—	—	0.15
	Chain pickerel	5	16.6	1.0	0.56	—	—	—	0.06
51. Kennebec River Hinckley, Maine	Smallmouth bass	5	11.4	0.8	0.80 (0.70)	—	<0.1	—	0.08
	Yellow perch	5	9.6	0.4	0.93	—	<0.1	—	0.08
	Yellow perch (R)	5	10.2	0.5	1.0	—	0.16	—	0.14
	White sucker	5	10.8	0.5	0.21	—	<0.1	—	0.30

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TABLE 3 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in selected fish and selenium residues in all fish, 1973—National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight				
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium	Selenium
52. Lake Champlain Burlington, Vt.	Chain pickerel	5	11.9	1.5	0.40	—	—	—	0.12
	Pumpkinseed	5	7.6	0.4	0.18	—	—	—	0.22
	Yellow perch	5	9.5	0.4	0.17	—	—	—	0.17
53. Merrimac River Lowell, Mass.	Carp	5	11.6	0.8	0.16	0.07	0.49	0.10	0.20
	Carp (R)	5	11.5	0.8	0.09	<0.05	0.56	0.06	0.14
	Yellow perch	5	11.5	0.9	0.53	0.05	0.24	<0.05	0.12
	White sucker	5	12.2	0.7	0.23 (0.25)	0.05 (0.05)	0.60 (0.7)	0.06 (<0.05)	0.17
2. Connecticut River Windsor Locks, Conn.	Yellow perch	5	9.3	0.4	0.08	—	0.44	<0.05	0.31
	White perch	5	10.1	0.6	0.39	—	0.43	0.08	0.83
	White perch (R)	5	9.5	0.5	0.45 (0.37)	— (0.08)	0.53 (0.5)	0.05 (<0.05)	1.13
	White catfish	5	12.6	1.1	0.17	—	0.54	0.13	0.25
3. Hudson River Poughkeepsie, N.Y.	Largemouth bass	5	11.9	0.9	—	—	<0.1 (0.1)	—	0.20
	Goldfish	5	10.6	1.0	—	—	0.58	—	0.26
	Pumpkinseed	5	5.8	0.1	—	—	0.28	—	0.30
	Pumpkinseed (R)	5	5.6	0.1	—	—	0.10	—	0.31
54. Raritan River Highland Park, N.J.	Carp	5	11.5	0.9	0.02	—	0.46	—	0.44
	White perch	2	8.0	0.3	0.11	—	ND	—	1.3 (1.34)
	Golden shiner	5	6.7	0.1	0.10	—	ND	—	0.23
	Golden shiner (R)	5	6.6	0.1	0.08	—	ND	—	0.26
4. Delaware River Camden, N.J.	White perch	5	9.0	0.4	—	—	0.28 (1.1)	—	1.5 (1.23)
	White perch (R)	5	9.1	0.4	—	—	0.26	—	1.1
	White sucker	5	14.5	1.3	—	—	0.33	—	0.80
	Brown bullhead	5	9.7	0.8	—	—	0.42	—	0.43
5. Susquehanna River Conowingo, Md.	White perch	5	7.6	0.2	—	—	0.73	—	2.1
	White perch (R)	5	7.5	0.2	—	—	0.36	—	0.18
	Carp	5	14.9	1.6	—	—	0.26	—	0.64
	Channel catfish	5	16.1	1.4	—	—	0.15	—	0.30 (0.35)
6. Potomac River Little Falls, Md.	Channel catfish	4	14.4	0.9	0.14	—	0.13	—	0.21
	Channel catfish (R)	4	11.2	0.4	<0.01	—	0.13	—	0.24
	Largemouth bass	3	7.9	0.2	0.07	—	0.25	—	0.21
	Largemouth bass (R)	3	8.2	0.2	0.13	—	0.17	—	0.13
	Redhorse	4	14.0	1.2	0.03	—	0.20	—	0.17
55. James River Richmond, Va.	Channel catfish	3	17.4	1.7	0.06	—	—	—	0.68
	Channel catfish (R)	2	19.7	2.3	0.07	—	—	—	0.44
	Largemouth bass	4	11.7	0.9	0.24	—	—	—	0.38
	Redhorse	3	15.8	1.9	0.02	—	—	—	0.44
7. Roanoke River Roanoke Rapids, N.C.	Carp	4	19.0	3.2	—	—	0.56	—	0.48
	Carp (R)	3	17.8	2.4	—	—	0.32	—	0.56
	Largemouth bass	3	9.6	0.4	—	—	0.25	—	0.26
	Channel catfish	5	12.9	0.6	—	—	0.26	—	0.16
8. Cape Fear River Elizabethtown, N.C.	Gizzard shad	3	12.7	1.0	0.12	—	—	—	0.26
	Yellow bullhead	5	8.4	0.4	0.14	—	—	—	0.13
	White catfish	5	15.6	1.6	0.24	—	—	—	0.22
	Largemouth bass	2	10.3	0.5	0.07	—	—	—	0.20
56. Pee Dee River Dongola, S.C.	Largemouth bass	2	13.4	1.6	0.59	—	—	—	0.30
	Carp	3	20.9	5.2	0.40	—	—	—	0.44
	Bluegill	5	6.7	0.2	0.27	—	—	—	0.43
	Bluegill (R)	4	6.6	0.2	0.27	—	—	—	0.33
9. Cooper River Summerton, S.C.	Largemouth bass	4	13.7	1.3	—	—	—	—	0.14
	Largemouth bass (R)	4	13.6	1.3	—	—	—	—	0.28
	Carp	2	21.3	3.1	—	—	—	—	0.16
	Bluegill	3	6.5	0.1	—	—	—	—	0.17
10. Savannah River Savannah, Ga.	Carp	3	23.2	6.4	0.28	—	—	—	0.30
	Redbreast sunfish	3	6.8	0.2	0.18	—	—	—	0.50
	Largemouth bass	3	11.6	1.0	0.73	—	—	—	0.12
	Largemouth bass (R)	3	12.7	1.1	0.73 (0.08)	—	—	—	0.05
57. Altamaha River Doctortown, Ga.	Bluegill	5	8.4	0.5	0.25	—	<0.1	—	0.14
	Bluegill (R)	5	8.2	0.5	0.60	—	<0.1	—	0.10
	Largemouth bass	5	12.7	1.1	0.53 (0.54)	—	<0.1	—	0.20
	Spotted sucker	4	16.9	2.0	0.25	—	<0.1	—	0.26

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TABLE 3 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in selected fish and selenium residues in all fish, 1973—National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight				
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium	Selenium
11. St. Johns River Welaka, Fla.	Striped mullet	3	17.6	2.5	—	0.28	—	—	0.42
	Striped mullet (R)	3	16.2	1.7	—	0.27	—	—	0.39
	Largemouth bass	3	9.2	0.4	—	0.16	—	—	0.24
	Channel catfish	4	10.7	0.4	—	0.13	—	—	0.19
12. St. Lucie Canal Indiantown, Fla.	Channel catfish	2	16.2	1.6	—	—	—	—	0.24
	Largemouth bass	3	10.6	0.5	—	—	—	—	0.26
	Largemouth bass (R)	3	13.2	1.0	—	—	—	—	0.34
	Bluegill	4	8.5	0.4	—	—	—	—	0.37
	Gulf Coast Streams								
58. Suwanee River Old Town, Fla.	Largemouth bass	5	10.7	0.6	0.35 (0.67)	—	—	—	0.36 (0.22)
	Redbreast sunfish	4	7.2	0.3	0.10	—	—	—	0.42
	Spotted sucker	3	14.5	1.6	0.10	—	—	—	0.60
	Spotted sucker (R)	3	14.6	1.6	0.20	—	—	—	2.12
13. Apalachicola River Jim Woodruff Dam, Fla.	Spotted sucker	3	19.3	2.7	—	—	—	—	0.38
	Channel catfish	3	11.0	0.4	—	—	—	—	0.42
	Largemouth bass	3	13.5	1.3	—	—	—	—	0.24
	Largemouth bass (R)	3	15.0	1.9	—	—	—	—	0.12
59. Alabama River Chrysler, Ala.	Largemouth bass	5	14.7	1.5	0.11	—	—	—	0.14
	Striped mullet	5	15.9	1.4	0.13	—	—	—	0.28
	Bluegill	5	7.5	0.2	0.09	—	—	—	0.28
	Bluegill (R)	5	7.1	0.2	0.10	—	—	—	0.14
14. Tombigbee River McIntosh, Ala.	Striped mullet	5	15.5	1.6	0.09	0.75	—	—	0.40
	Carp	3	21.0	4.6	0.07	0.29	—	—	0.44
	Largemouth bass	5	12.6	1.0	0.25	0.15	—	—	0.24
	Largemouth bass (R)	5	12.0	0.7	0.65 (0.66)	0.15	—	—	0.16
15. Mississippi River Luling, La.	Freshwater drum	4	13.4	1.3	—	—	0.19	0.12	0.42
	Blue catfish	5	14.5	1.1	—	—	<0.1	<0.05	0.21
	Blue catfish (R)	5	14.5	1.1	—	—	0.12	0.21	0.12 (0.23)
60. Brazos River Richmond, Tex.	Longnose gar	5	23.8	0.9	0.03	—	0.85	—	0.33
	Longnose gar (R)	5	22.2	0.8	0.02	—	<0.1	—	0.56
	Blue catfish	4	16.1	1.4	0.11	—	0.32	—	0.74
	River carpsucker	4	10.0	0.4	0.13	—	0.11	—	0.42
61. Colorado River Wharton, Tex.	Channel catfish	5	12.1	0.6	0.05	<0.05	0.40	—	0.65
	Channel catfish (R)	5	13.0	0.7	0.05	0.08	0.36	—	1.0
	Spotted bass	1	12.0	1.0	0.03	0.07	<0.1	—	0.05
	River carpsucker	2	15.8	1.6	0.03	0.05 (0.09)	0.32 (0.6)	—	0.28
	Carp	2	20.1	4.1	0.05	<0.05	0.19	—	<0.05
62. Nueces River Mathis, Tex.	Smallmouth buffalo	5	15.7	2.4	—	—	—	—	0.18
	Smallmouth buffalo (R)	5	14.1	2.0	—	—	—	—	0.18
	Blue catfish (R)	5	17.7	1.9	—	—	—	—	0.14
	White crappie	5	9.4	0.5	—	—	—	—	0.20
	Gizzard shad	5	10.5	0.4	—	—	—	—	0.40 (0.56)
	Largemouth bass	5	13.2	1.3	—	—	—	—	0.16
16. Rio Grande Brownsville, Tex.	Channel catfish	4	13.4	0.7	—	—	0.13	—	0.20
	Channel catfish (R)	4	12.1	0.4	—	—	0.13	—	0.16
	Gizzard shad	2	10.0	0.3	—	—	0.23	—	0.25
	Channel catfish	5	12.0	0.5	—	—	0.18	—	0.16
63. Rio Grande Elephant Butte, N. Mex.	Channel catfish	5	11.9	0.4	0.10	0.08	—	—	0.08
	Channel catfish (R)	5	12.8	0.6	0.06	<0.05	—	—	0.13
	Carp	5	14.3	1.2	0.11	0.05	—	—	0.23
	Largemouth bass	5	12.5	1.3	0.05	0.17	—	—	0.20
64. Rio Grande Alamosa, Colo.	White sucker	5	12.9	0.9	—	—	0.25	—	0.07
	White sucker (R)	5	12.3	0.7	—	—	0.60	—	0.08
	Brown trout	3	13.0	1.0	—	—	0.10	—	0.08
65. Pecos River Red Bluff Lake, Tex.	Gizzard shad	5	8.2	0.1	—	—	—	—	0.95
	Gizzard shad (R)	5	9.3	0.3	—	—	—	—	0.85
	Channel catfish	5	13.5	0.8	—	—	—	—	1.3
	Smallmouth buffalo	5	14.4	1.4	—	—	—	—	1.0 (0.80)
17. Genessee River Scottsville, N.Y.	Walleye	5	16.1	1.4	0.23	—	—	—	0.29
	Walleye (R)	5	17.0	1.6	0.08	—	—	—	0.39
	White sucker	5	15.4	1.5	0.21	—	—	—	0.49
	Rock bass	5	7.6	0.4	0.21	—	—	—	0.27

(Continued next page)

TABLE 3 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in selected fish and selenium residues in all fish, 1973—National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight				
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium	Selenium
66. St. Lawrence River Massena, N.Y.	Northern pike	3	21.4	2.3	0.25	—	—	—	0.34 (0.36)
	Yellow perch	5	7.0	0.2	0.09	—	—	—	0.33
	Yellow perch (R)	5	7.2	0.2	0.10	—	—	—	0.30
	White sucker	5	14.8	1.4	0.11	—	—	—	0.33
18. Lake Ontario Port Ontario, N.Y.	White perch	5	9.0	0.5	0.18 (0.16)	0.24	0.34	—	0.56 (0.92)
	Rock bass	5	8.3	0.5	0.39	0.20	0.46	—	0.23
	Yellow perch	5	9.9	0.5	0.24	0.18	0.23	—	0.17
	Yellow perch (R)	5	9.6	0.5	0.21	0.11	<0.1	—	0.29
19. Lake Erie Erie, Pa.	Yellow perch	5	8.7	0.4	—	—	—	—	0.64
	Yellow perch (R)	5	9.2	0.4	—	—	—	—	0.44
20. Lake Huron Bay Port, Mich.	Carp	5	15.2	1.8	—	0.18	—	—	0.64
	Yellow perch	5	9.5	0.4	—	0.16	—	—	0.64
	Yellow perch (R,	5	9.1	0.4	—	0.09	—	—	0.86
	Channel catfish	3	15.6	1.3	—	0.10	—	—	0.80
21. Lake Michigan Sheboygan, Wis.	Bloater	5	10.8	0.4	0.04	0.42 (0.81)	—	—	0.43
	Bloater	5	11.0	0.4	0.07	1.24	—	—	0.44
	Yellow perch	5	9.2	0.3	0.03	0.16	—	—	0.64
	Yellow perch (R)	5	8.8	0.3	0.11	<0.05	—	—	0.21
	Lake trout	5	21.4	3.2	0.11	0.65	—	—	0.80
	Lake trout (R)	5	21.7	3.3	0.10	0.68	—	—	0.57
22. Lake Superior Bayfield, Wis.	Bloater	5	10.3	0.3	0.09	0.60	<0.1	—	0.54
	Bloater (R)	5	10.6	0.3	0.09	0.68	<0.1	—	0.20
	Lake whitefish	4	21.2	3.3	0.08	0.56	0.18	—	2.4
	Lake trout	5	26.1	5.9	0.26	0.27	<0.1	—	0.26
	Lake trout (R)	5	27.0	6.5	0.40	0.43	<0.1	—	0.16
Mississippi River System									
67. Allegheny River Natrona, Pa.	Smallmouth bass	5	10.8	0.8	0.19	—	0.32	—	0.33
	Walleye	5	15.3	1.2	0.30	—	0.11	—	0.24
	Carp	5	16.8	2.3	0.08	—	0.30	—	0.23
	Carp (R)	5	17.2	2.5	0.09	—	0.26	—	0.44
23. Kanawha River Winfield, W. Va.	Brown bullhead	3	11.9	0.8	—	—	—	—	0.13
	Carp	5	11.4	0.7	—	—	—	—	0.36
	Pumpkinseed	5	7.6	0.2	—	—	—	—	0.30
	Pumpkinseed (R)	5	9.0	0.4	—	—	—	—	0.20
68. Wabash River New Harmony, Ind.	Channel catfish	5	14.6	0.9	0.11	—	0.10	<0.05	0.36
	Carp	5	17.5	2.9	0.22	—	0.16	<0.05 (0.10)	0.36
	Carp (R)	5	18.9	3.6	0.11	—	0.23	0.13	0.38
	White crappie	5	9.2	0.4	0.28	—	0.22 (0.2)	<0.05	0.21
24. Ohio River Marietta, Ohio	Spotted sucker	5	12.4	0.7	ND	—	<0.1	—	0.50
	Channel catfish	5	15.0	1.0	0.16	—	<0.1	—	0.30
	Channel catfish (R)	5	14.3	0.9	0.22	—	<0.1	—	0.43
	Carp	5	14.9	1.8	0.10	—	<0.1	—	0.41
69. Ohio River Cincinnati, Ohio	Carp	5	16.4	2.2	—	0.10	—	0.17	0.14
	Channel catfish	5	16.9	1.5	—	0.05	—	0.09	0.12
	Channel catfish (R)	5	16.9	1.5	—	0.05	—	0.05	0.23
	Sauger	5	10.4	0.4	—	0.10	—	<0.05	0.21
70. Ohio River Metropolis, Ill.	Carp	5	17.6	2.6	—	0.15	—	—	0.36
	White crappie	5	10.9	0.6	—	0.07	—	—	0.23
	White crappie (R)	5	10.0	0.5	—	0.20	—	—	0.14
	Channel catfish	5	14.6	1.1	—	0.05	—	—	0.23
25. Cumberland River Clarksville, Tenn.	Largemouth bass	5	15.3	2.3	0.40	—	0.28	—	0.50
	Bluegill	5	6.0	0.1	0.08	—	<0.1	—	0.41
	Bluegill (R)	5	5.8	0.1	0.10	—	<0.1	—	0.34
	Carp	5	15.1	1.7	0.09	—	0.20	—	0.41
71. Tennessee River Savannah, Tenn.	Carp	3	17.1	2.6	0.26	<0.05	<0.1	—	0.54
	Carp (R)	3	17.9	3.0	0.38	<0.05	0.20	—	0.46
	Bluegill	4	5.5	0.1	0.29	<0.05	<0.1	—	0.38
	Channel catfish	1	16.3	2.1	0.45	0.07	0.12	—	0.36
	Largemouth bass	2	11.1	0.8	0.16 (0.48)	0.10	<0.1	—	0.25
72. Wisconsin River Woodman, Wis.	Smallmouth bass	5	12.1	1.0	0.13	0.07	—	—	0.46
	Carp	5	21.3	4.6	0.25	0.06	—	—	0.64
	Carp (R)	5	20.0	4.0	0.22	0.08	—	—	0.47
	Sauger	5	14.3	0.7	0.30	<0.05	—	—	0.18

(*Continued next page*)

TABLE 3 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in selected fish and selenium residues in all fish, 1973—National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight				
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium	Selenium
73. Des Moines River Keosauqua, Iowa	Carp	5	11.8	0.8	—	—	0.19	—	0.36
	Carp (R)	5	11.8	0.8	—	—	0.44	—	0.30
	Channel catfish	4	10.7	0.4	—	—	0.70	—	0.24
	Walleye	7	7.4	0.1	—	—	0.10	—	0.20
26. Illinois River Beardstown, Ill.	Black crappie	4	5.6	0.1	—	0.11	—	—	0.70
	Freshwater drum	5	9.4	0.4	—	0.15	—	—	0.33
	Carp	5	12.2	1.0	—	0.15	—	—	0.64
							(0.1)		(0.44)
	Carp (R)	5	12.6	1.1	—	0.17	—	—	0.39
74. Mississippi River Little Falls, Minn.	White sucker	1	17.0	2.1	0.22	0.10	—	—	0.11
	Yellow bullhead	2	9.9	0.6	0.50	<0.05	—	—	0.16
	Walleye	2	10.0	0.4	0.15	<0.05	—	—	0.16
27. Mississippi River Guttenburg, Iowa	Carp	5	17.8	2.7	—	—	—	—	0.18
	Largemouth bass	5	12.2	1.2	—	—	—	—	0.30
	Bluegill	5	7.3	0.3	—	—	—	—	0.54
	Bluegill (R)	5	4.7	0.1	—	—	—	—	0.85
75. Mississippi River Cape Girardeau, Mo.	Carp	5	14.7	1.7	0.04	—	—	—	0.62
	Carp (R)	5	12.4	1.1	0.08	—	—	—	0.60
	White crappie	5	9.0	0.4	0.08	—	—	—	0.35
	Channel catfish	5	12.3	0.7	0.10	—	—	—	0.73
76. Mississippi River Memphis, Tenn.	Flathead catfish	3	15.1	1.6	—	0.07	0.10	<0.05	0.36
	Carp	3	19.7	4.1	—	0.07	0.30	<0.05	0.60
	Freshwater drum	ND	14.9	1.8	—	0.27	0.36	<0.05	0.77
	Freshwater drum (R)	ND	10.5	0.8	—	0.20	0.40	<0.05	0.04
							(1.0)	(<0.05)	(0.60)
28. Arkansas River Pine Bluff, Ark.	Smallmouth buffalo	3	17.6	3.2	—	0.08	—	—	0.29
	Smallmouth buffalo (R)	3	19.2	4.1	—	0.15	—	—	0.18
	Flathead catfish	3	22.9	5.6	—	0.12	—	—	0.17
	Carp	4	22.9	6.2	—	<0.05	—	—	0.52
29. Arkansas River Keystone Reservoir, Okla.	Carp	5	12.4	0.9	0.03	<0.05	—	<0.05	0.19
	Largemouth bass	5	9.5	0.5	0.05	ND	—	<0.05	0.32
	Bluegill	5	5.6	0.1	0.04	<0.05	—	<0.05	0.29
	Bluegill (R)	5	5.6	0.1	0.04	<0.05	—	<0.05	0.24
77. Arkansas River John Martin Reservoir, Colo.	Carp	5	14.2	1.4	—	—	—	—	1.3
									(3.28)
	Carp (R)	5	14.4	1.5	—	—	—	—	1.4
	Channel catfish	5	14.9	1.0	—	—	—	—	0.85
	Black bullhead	2	9.8	0.5	—	—	—	—	0.24
78. Verdigris River Oologah, Okla.	Carp	5	16.7	2.4	—	—	0.26	—	0.68
	Largemouth bass	5	10.2	0.5	—	—	0.26	—	0.32
	Bluegill	5	6.0	0.1	—	—	0.24	—	0.33
	Bluegill (R)	5	5.9	0.1	—	—	0.19	—	0.31
79. Canadian River Eufaula, Okla.	Bluegill	5	5.4	0.1	—	—	—	—	0.12
	Bluegill (R)	5	5.0	0.1	—	—	—	—	0.16
	Largemouth bass	5	11.0	0.7	—	—	—	—	0.14
	Carp	5	13.7	1.1	—	—	—	—	0.15
30. White River DeValls Bluff, Ark.	Channel catfish	3	15.2	1.2	—	<0.05	—	—	0.44
	Channel catfish (R)	3	15.3	1.2	—	0.06	—	—	0.40
	Smallmouth buffalo	4	15.8	2.8	—	<0.05	—	—	0.40
	Carp	4	20.2	4.0	—	<0.05	—	—	0.53
80. Yazoo River Redwood, Miss.	Channel catfish	3	18.7	1.9	—	—	—	<0.05	0.22
	Smallmouth buffalo	3	17.3	2.6	—	—	—	ND	ND
	Smallmouth buffalo (R)	3	17.8	2.9	—	—	—	<0.05	0.36
	Carp	3	22.7	6.1	—	—	—	0.09	0.48
								(<0.05)	(0.67)
81. Red River Alexandria, La.	Smallmouth buffalo	1	17.0	3.9	—	—	—	—	0.20
	Blue catfish	5	12.3	0.5	—	—	—	—	0.14
	Freshwater drum	5	13.1	1.0	—	—	—	—	0.22
	Freshwater drum (R)	5	13.0	1.0	—	—	—	—	0.26
	Carp	1	21.7	3.8	—	—	—	—	0.24
82. Red River Lake Texoma, Okla.	Bluegill	5	5.3	0.1	—	0.10	—	—	0.13
	Bluegill (R)	5	5.3	0.1	—	0.08	—	—	0.15
	Carp	4	19.2	3.2	—	0.28	—	—	0.16
	Largemouth bass	5	11.2	0.7	—	0.65	—	—	0.17
83. Missouri River Hermann, Mo.	Carp	3	19.4	4.0	—	—	—	—	0.72
	Carp (R)	3	21.6	4.7	—	—	—	—	0.60
	Freshwater drum	5	16.8	3.0	—	—	—	—	0.68
	Bigmouth buffalo	4	18.5	3.6	—	—	—	—	0.38

(*Continued next page*)

TABLE 3 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in selected fish and selenium residues in all fish, 1973—National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight				
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium	Selenium
31. Missouri River Nebraska City, Nebr.	Carp	5	13.3	1.4	—	—	—	—	0.64
	Carp (R)	5	13.6	1.5	—	—	—	—	1.0
	Goldeye	4	14.3	1.1	—	—	—	—	0.67
							(0.4)		(1.16)
	White crappie	4	9.7	0.6	—	—	—	—	0.71
32. Missouri River Garrison Dam, N. Dak.	Walleye	5	16.3	1.4	—	0.05	—	<0.05	0.32
	Goldeye	5	12.8	0.8	—	0.05	—	<0.05	0.22
	Goldeye (R)	5	12.6	0.8	—	<0.05	—	<0.05	0.18
	Carp	5	15.2	1.7	—	0.07	—	<0.05	0.18
33. Missouri River Great Falls, Mont.	Longnose sucker	3	15.6	1.7	0.03	—	0.38	—	0.34
	Goldeye	5	12.5	0.6	0.08	—	0.29	—	1.4
	Goldeye (R)	3	12.8	0.7	0.02	—	0.26	—	1.5
84. Big Horn River Hardin, Mont.	Carp	4	16.9	2.7	—	—	—	—	1.0
	Channel catfish	3	22.5	4.5	—	—	—	—	1.0
	Goldeye	5	12.6	0.7	—	—	—	—	1.6
	Goldeye (R)	5	12.8	0.7	—	—	—	—	1.6
									(2.59)
85. Yellowstone River Sidney, Mont.	Carp	2	12.7	0.9	—	<0.05	0.17	—	0.48
	Goldeye	5	11.3	0.5	—	0.20	0.10	—	0.72
	Goldeye (R)	5	10.7	0.4	—	0.20	0.28	—	0.72
	Channel catfish	5	16.7	1.4	—	0.05	<0.1	—	0.64
86. James River Olivet, S. Dak.	Channel catfish	5	14.8	0.8	—	—	<0.10	—	0.24
	Goldeye	5	13.6	1.0	—	—	<0.10	—	0.60
	Goldeye (R)	5	13.9	0.9	—	—	<0.10	—	0.60
	Carp	1	10.6	0.7	—	—	<0.10	—	0.36
87. North Platte River Lake McConaughy, Nebr.	Carp	5	18.1	2.8	—	<0.05	—	—	0.72
	Carp (R)	5	17.2	2.3	—	0.26	—	—	0.72
	Walleye	5	16.3	1.2	—	0.24	—	—	0.67
	Channel catfish	5	15.0	1.3	—	0.12	—	—	0.67
88. South Platte River Brule, Nebr.	White sucker	8	7.5	0.3	0.07	—	—	—	0.16
	Green sunfish	13	3.3	<0.1	0.05	—	—	—	0.33
	Carp	5	14.0	1.5	0.06	—	—	—	0.71
	Carp (R)	5	13.3	1.4	0.05	—	—	—	1.4
89. Platte River Louisville, Nebr.	Carp	5	13.5	1.5	—	—	—	—	0.88
	Carp (R)	5	12.9	1.2	—	—	—	—	0.84
	Channel catfish	4	12.5	0.7	—	—	—	—	0.92
	White crappie	4	8.6	0.4	—	—	—	—	0.80
90. Kansas River Bonner Springs, Kans.	Carp	5	16.1	2.3	—	—	—	—	0.80
	Carp (R)	5	16.5	2.3	—	—	—	—	0.72
	Freshwater drum	5	11.4	0.6	—	—	—	—	0.92
	Gizzard shad	5	8.6	0.2	—	—	—	—	0.60
Hudson Bay Drainage									
34. Red River Noyes, Minn.	Goldeye	3	12.6	0.7	0.09	—	<0.10	—	1.7
	Channel catfish	2	16.0	1.5	0.07	—	<0.10	—	0.56
	Sauger	5	12.0	0.5	0.24	—	<0.10	—	0.28
	Sauger (R)	5	11.8	0.5	0.30	—	<0.10	—	0.23
					(0.38)		(0.3)		
Colorado River System									
35. Green River Vernal, Utah	Channel catfish	5	11.6	0.5	—	<0.05	—	—	0.64
	Channel catfish (R)	5	11.9	0.4	—	<0.05	—	—	0.73
	Carp	5	15.9	2.2	—	<0.05	—	—	0.56
	Flannelmouth sucker	4	17.8	1.9	—	0.08	—	—	0.49
36. Colorado River Imperial Reservoir, Ariz.	Largemouth bass	4	11.3	0.9	—	—	—	—	2.1
									(2.56)
	Carp	3	18.1	2.8	—	—	—	—	3.2
									(2.32)
	Bluegill	3	5.8	0.2	—	—	—	—	2.5
	Bluegill (R)	3	5.9	0.2	—	—	—	—	0.44
91. Colorado River Lake Havasu, Ariz.	Carp	3	17.4	3.1	—	<0.05	—	—	3.0
							(0.3)		(2.91)
	Black crappie	1	12.9	1.3	—	0.19	—	—	2.1
	Largemouth bass	4	9.8	0.5	—	0.10	—	—	1.4

(*Continued next page*)

TABLE 3 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in selected fish and selenium residues in all fish, 1973—National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight				
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium	Selenium
92. Colorado River Lake Mead, Nev.	Largemouth bass	5	12.6	1.1	—	—	0.22	—	1.4
	Largemouth bass (R)	5	12.0	1.0	—	—	0.12	—	1.8
	Channel catfish	5	15.9	1.2	—	—	0.18	—	1.4 (0.31)
	Carp	5	16.8	2.4	—	—	0.20	—	1.6 (1.26)
93. Colorado River Lake Powell, Ariz.	Largemouth bass	4	14.7	2.3	0.16 (0.20)	0.39	—	—	1.0 (1.39)
	Carp	4	13.6	1.1	0.05	0.09	—	—	0.36
	Carp (R)	4	13.8	1.1	0.13	0.09	—	—	1.3
	Rainbow trout	5	16.7	2.3	0.09	0.26	—	—	2.3
94. Gila River San Carlos Reservoir, Ariz.	Largemouth bass	5	12.9	1.3	—	<0.05	—	—	0.56
	Largemouth bass (R)	5	12.6	1.1	—	0.21	—	—	0.23
	Carp	3	12.8	1.0	—	<0.05	—	—	0.56
	Bluegill	5	6.2	0.2	—	0.15	—	—	0.64
Interior Basins									
37. Truckee River Fernley, Nev.	Carp	4	15.2	1.7	0.22 (<0.05)	—	0.42 (<0.10)	—	0.26 (1.17)
	Carp (R)	4	17.6	2.6	0.24	—	0.33	—	0.28
	Largemouth bass	3	12.6	1.3	0.49	—	0.32	—	0.13
	Brown bullhead	5	10.3	0.7	0.17	—	0.40	—	0.13
38. Utah Lake Provo, Utah	Carp	5	17.9	2.6	—	0.13	—	—	0.19
	White bass	5	10.4	0.4	—	0.16	—	—	0.32
	Black bullhead	5	11.1	0.7	—	<0.05	—	—	0.22
	Black bullhead (R)	5	11.3	0.7	—	<0.05	—	—	0.18
95. Bear River Preston, Idaho	Largescale sucker	5	18.6	2.6	—	—	—	—	0.34
	Carp	4	14.1	1.6	—	—	—	—	0.26
	Yellow perch	5	8.9	0.3	—	—	—	—	0.34
	Yellow perch (R)	5	7.9	0.2	—	—	—	—	0.34
California Streams									
39. Sacramento River Sacramento, Calif.	White catfish	1	11.8	0.6	0.08	<0.05	0.42	<0.05	0.18
	Carp	5	18.8	2.9	0.03 (0.21)	0.50	0.46	<0.05 (0.09)	0.33
	Carp (R)	2	20.3	4.2	0.08	0.40	0.32	<0.05	0.76
40. San Joaquin River Los Banos, Calif.	Channel catfish	5	10.4	0.3	—	<0.05	—	<0.05	0.18
	Channel catfish (R)	5	12.7	0.6	—	0.07	—	<0.05	0.27
	Carp	5	13.7	1.2	—	<0.05	—	<0.05	0.28
	White catfish	5	12.0	0.7	—	<0.05	—	<0.05	0.20
Columbia River System									
43. Salmon River Riggins, Idaho	Smallmouth bass	5	13.2	1.4	0.22	0.05	—	—	0.83
	Largescale sucker	5	17.5	1.8	0.15	0.20	—	—	0.32
	Brown bullhead	5	7.5	0.2	0.13	0.08	—	—	0.56
	Brown bullhead (R)	5	8.3	0.3	0.10	<0.05	—	—	0.53
41. Snake River Hagerman, Idaho	Largescale sucker	5	15.9	1.7	0.03	—	—	—	0.27
	Largescale sucker (R)	5	16.1	1.5	0.07	—	—	—	0.20
	Northern squawfish	5	15.4	1.4	0.03	—	—	—	0.30
	Rainbow trout	5	14.8	1.5	0.03	—	—	—	0.22
42. Snake River Lewistown, Idaho	Black crappie	5	9.6	0.7	0.13	0.06	—	<0.05	0.20
	Black crappie (R)	5	9.8	0.6	0.10	<0.05	—	<0.05	0.24
	Largescale sucker	5	17.2	1.9	0.04	0.20	—	<0.05	0.16
	Carp	5	17.3	2.7	0.06	0.18	—	0.06 (0.05)	0.30
96. Snake River Ice Harbor, Wash.	Largescale sucker	5	14.0	1.0	0.05	0.12	—	—	0.37
	Largescale sucker (R)	5	14.6	1.0	0.07	0.13	—	—	0.38
	Channel catfish	5	16.3	1.4	0.08	<0.05	—	—	0.18
	Northern squawfish	5	16.2	1.6	0.65	<0.05	—	—	0.18
44. Yakima River Granger, Wash.	Largescale sucker	5	15.3	1.3	0.04	—	—	—	0.20
	Largescale sucker (R)	5	14.4	1.2	0.03	—	—	—	0.13
	Largemouth bass	3	13.8	1.7	0.18	—	—	—	0.10
	Carp	5	13.4	1.2	0.07	—	—	—	0.22
45. Willamette River Oregon City, Oreg.	Largescale sucker	5	16.1	1.5	0.08	—	—	—	0.09
	Largescale sucker (R)	5	16.7	1.6	0.20	—	—	—	0.05
	Northern squawfish	5	16.0	1.6	0.65	—	—	—	<0.05
	Carp	5	14.3	1.3	0.15	—	—	—	0.18

(*Continued next page*)

TABLE 3 (cont'd.). *Concentrations of mercury, arsenic, lead, and cadmium in selected fish and selenium residues in all fish, 1973—National Pesticide Monitoring Program*

Station Number and Location	Species	No. Fish	Average Size		Residues, mg/kg wet weight				
			Length, in.	Weight, lb	Mercury	Arsenic	Lead	Cadmium	Selenium
46. Columbia River Bonneville Dam, Oreg.	Largescale sucker	5	17.7	1.9	0.32	<0.05	0.32	0.13	0.13
	Largescale sucker (R)	5	17.6	1.8	0.32	0.08	0.39	0.05	0.06
	Northern squawfish	5	11.9	0.6	0.85	<0.05	0.24	<0.05	0.20
	Carp	5	13.7	1.1	0.06	0.08	0.24	<0.05	0.20
97. Columbia River Pasco, Wash.	Carp	5	11.7	0.8	—	0.18	0.15	<0.05 (<0.05)	0.93
	Carp (R)	5	12.2	0.8	—	0.18	<0.10	<0.05	0.48
	Largescale sucker	5	14.2	1.1	—	0.13	<0.10	<0.05	0.06
	Northern squawfish	5	13.6	0.9	—	0.05	<0.10	<0.05	0.24
98. Columbia River Grand Coulee, Wash.	Northern squawfish	5	13.0	0.9	0.16 (0.21)	<0.05	0.30	0.14 (0.11)	0.14
	Bridgelip sucker	5	14.3	1.1	0.03	0.27	0.53	0.08	0.20
	Bridgelip sucker (R)	5	13.7	0.9	0.08	0.18	1.0	0.07	0.26
	Walleye	5	14.4	1.1	0.15	0.05	0.22	<0.05	0.26
Pacific Coast Streams									
47. Klamath River Hornbrook, Calif.	Klamath sucker	5	14.9	1.6	0.04	—	—	0.06	0.32
	Yellow perch	5	8.1	0.3	0.05	—	—	<0.05	0.10
	Yellow perch (R)	5	8.0	0.2	0.04	—	—	<0.05	0.13
	Largemouth bass	5	7.7	0.3	0.10	—	—	<0.05	0.10
48. Rogue River Gold Ray Dam, Oreg.	Carp	4	11.9	1.4	0.02	—	—	—	0.20
	Brown bullhead	5	9.4	0.4	0.12	—	—	—	0.13
	Brown bullhead (R)	5	9.0	0.4	0.02	—	—	—	0.13
	Black crappie	5	10.3	0.7	0.15	—	—	—	0.12
49. Chena River Fairbanks, Alaska	Longnose sucker	4	14.3	1.3	—	—	—	<0.05	0.58
	Round whitefish	3	11.1	0.4	—	—	—	<0.05	1.4
	Round whitefish (R)	3	11.3	0.4	—	—	—	<0.05	1.2
	Arctic grayling	5	11.6	0.6	—	—	—	<0.05	1.2 (0.32)
50. Kenai River Soldatna, Alaska	Round whitefish	5	10.8	0.4	—	<0.05	—	—	1.3
	Rainbow trout	5	13.4	1.1	—	0.11	—	—	0.64
	Lake trout	5	15.2	1.0	—	0.08	—	—	0.52
	Lake trout (R)	5	14.9	0.9	—	0.07	—	—	0.56
Hawaiian Streams									
99. Waikele Stream Waipahu, Hawaii	Tilapia	2	5.8	0.1	—	0.11	<0.1 (0.4)	—	0.92 (1.35)
	Cuban limia	21	3.0	<0.1	—	<0.05	<0.1	—	1.0
	Chinese catfish	2	8.9	0.2	—	<0.05	0.34	—	1.0
	Chinese catfish (R)	2	8.4	0.2	—	<0.05	0.32 (0.8)	—	0.93 (1.22)
100. Manoa Stream Honolulu, Hawaii	Chinese catfish	2	9.3	0.3	—	0.06	0.70	—	0.58
	Chinese catfish (R)	2	10.0	0.3	—	0.09	0.93 (0.8)	—	0.54
	Tilapia	2	9.8	0.5	—	0.19	0.63	—	0.25
	Cuban limia	26	2.7	0.01	—	0.15	1.4	—	0.29

NOTE: — = residues not determined.
R = replicate sample.
ND = not detected.
Numbers in parentheses are results of cross-check analyses.
[1]Redhorse = *Moxostoma* sp.

TABLE 4. *Summary of mercury, arsenic, lead, cadmium, and selenium residues in fish, 1971-73—National Pesticide Monitoring Program*

Year	No. Stations Represented	Total Composites Analyzed	Number of Composites							
			With Residues		Less than Detectable Levels[1]		From Detectable Levels to 0.5 mg/kg		>0.5 mg/kg	
			No.	%	No.	%	No.	%	No.	%
Mercury										
1971	100	584	576	99	1	<1	534	93	41	7
1972	98	391	391	100	2	<1	373	95	16	4
1973	47	196	195	100	1	<1	179	92	15	8
Arsenic										
1971	100	584	559	96	210	38	337	60	12	2
1972	98	391	388	99	98	25	291	74	2	1
1973	39	171	171	100	47	27	116	68	8	5
Lead										
1971	100	584	327	56	44	13	261	80	22	7
1972	98	391	390	100	118	30	198	51	73	19
1973	36	161	161	100	42	26	102	63	17	11
Cadmium										
1971	100	584	443	76	329	74	113	26	1	0
1972	98	391	390	99	273	70	100	26	17	4
1973	17	75	75	100	53	71	22	29	0	0
Selenium										
1972	98	391	386	99	0	0	217	56	169	44
1973	100	444	444	100	3	1	308	69	133	30

[1]Detectable levels of mercury, arsenic, lead, cadmium, and selenium were 0.01, 0.05, 0.10, 0.05, and 0.05 mg/kg, respectively.

Nationwide Residues of Mercury, Lead, Cadmium, Arsenic, and Selenium in Starlings, 1973

Donald H. White,[1] Jerry R. Bean,[2] and Jerry R. Longcore [3]

ABSTRACT

Starlings (Sturnus vulgaris) *collected in 1973 at 51 sites throughout the continental United States were analyzed for mercury, lead, cadmium, arsenic, and selenium. All samples contained detectable levels of these elements. In general, residues were low: mercury residues ranged from <0.01 to 0.20 ppm; lead, from <0.10 to 3.20 ppm; cadmium, from <0.05 to 0.20 ppm; arsenic, from <0.05 to 1.40 ppm; and selenium, from 0.10 to 1.10 ppm. There was a significant overall decline in mercury and lead residues in starlings since 1971, and a significant increase in arsenic residues. Lead residues were significantly higher in starlings from urban areas than from rural areas.*

Introduction

The Fish and Wildlife Service, U.S. Department of Interior, began nationwide monitoring of organochlorines in starlings (*Sturnus vulgaris*) in 1967-68 as part of the National Pesticide Monitoring Program. The starling monitoring program was modified to include analyses for mercury and lead in 1970, and cadmium and arsenic in 1971 (*2,3*). Residue data from these collections were to serve as a baseline against which future residue levels might be compared. Analysis for selenium was added in 1973. This paper presents results of analyses of the 1973 starling collection including residue levels of mercury, lead, cadmium, arsenic, and selenium from each collecting site; a comparison of averages of mercury, lead, cadmium, and arsenic residues from the 1971 and 1973 collections; and a comparison of residues from urban and rural collecting sites in 1973.

Collection Methods

Earlier papers discuss the sampling design and collecting procedures in detail (*2,3*). Twenty-five preselected sites were established in 1970 and 28 new sites were added in 1971. The sites were chosen to reflect varying environmental conditions representing broad geographic areas and including differing degrees of human activity and related pollution sources (*3*). Ten-bird pools of starlings were obtained in November and December 1973 from 51 of the 53 preselected sites (Figure 1) by trapping or shooting with shot other than lead. Six samples contained less than 10 birds; these sites are identified in Table 1. Each pool of birds was wrapped in aluminum foil, placed in a polyethylene bag, frozen as soon as possible, and shipped to the Denver Wildlife Research Center for analysis.

Analytical Procedures

Prior to analysis the feet, beaks, wing tips, and skins were removed from birds in each composite sample; the sample was weighed and then ground in a Hobart food chopper. Four 1-g aliquots were taken from each sample homogenate: 1 g each for mercury, arsenic, and selenium analyses, and 1 g for lead and cadmium analyses.

MERCURY ANALYSIS

The presence of mercury was determined by the method of Okuno et al. (*4*) except that the samples were dried in a microwave oven for 5 minutes and then ignited with oxygen in a combustion flask. The combustion products were collected in dilute HCl and the acid solution was reduced with a 20 percent hydroxylamine hydrochloride solution. The mercury was extracted from the solution by amalgamating it onto a silver wire. The silver wire was placed in an absorption cell of the spectrophotometer and heated, by its own electrical resistance, to volatilize the mercury. Spectrophotometric responses were recorded and micrograms of mercury in the samples were read from a standard curve. A fresh standard curve for 0.001 to

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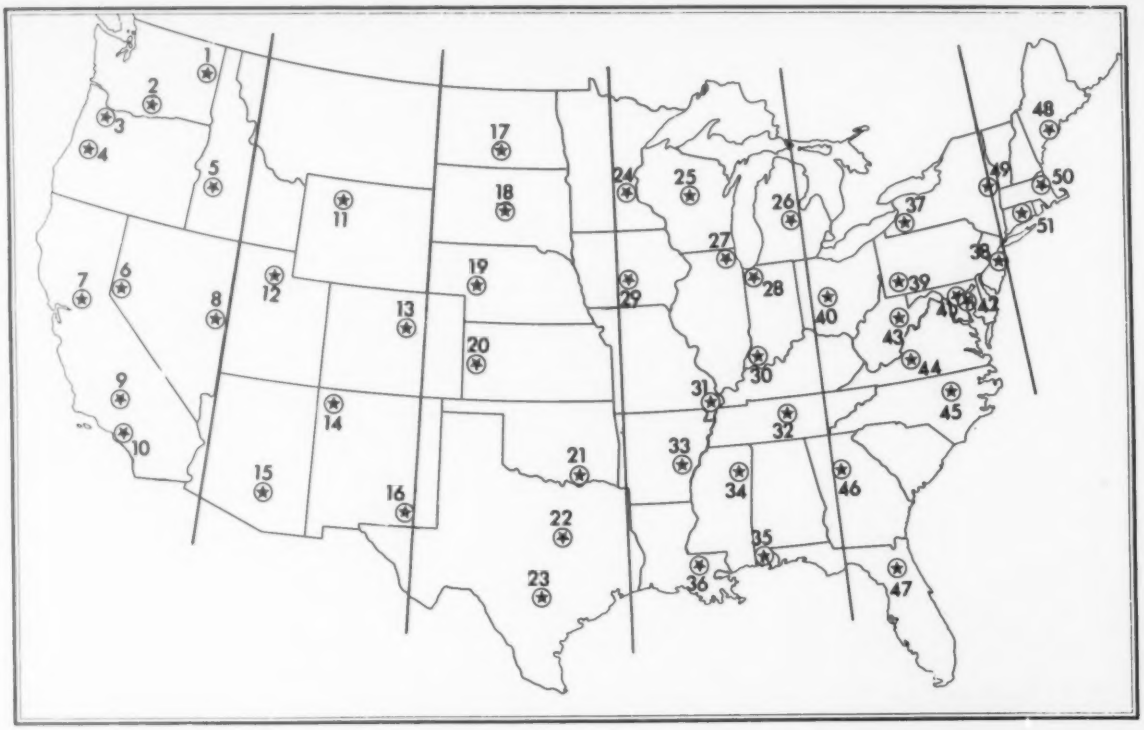

FIGURE 1. *Starling collecting sites, 1973*

0.2 μg mercury was prepared daily. Determinations were made with a Jarrell-Ash Model 82-360 spectrophotometer. The limit of quantification for mercury was 0.01 ppm on a wet-weight basis.

LEAD AND CADMIUM ANALYSIS

The method for detecting lead and cadmium was developed by the Denver Wildlife Research Center (Okuno, 1975: personal communication). A 1-g aliquot was placed in a 50-ml beaker and ashed with a mixture of nitric and perchloric acids; the beaker then was transferred to a 500°C muffle furnace for 4 hours. After cooling, 1 ml concentrated HNO_3 was added and the beaker was heated until the sample was dry and white. After cooling, 1 ml concentrated HNO_3 and 2 ml distilled water were added and the beaker was warmed for 5 minutes on a hotplate. The solution was adjusted to a pH of about 3 and transferred to a 125-ml separatory funnel. One ml of a 1 percent aqueous solution of ammonium pyrrolidine-dithiodicarbamate was added to the funnel; the funnel was swirled and allowed to stand for 2 minutes. Ten ml of methyl isobutyl-ketone was added, the funnel was shaken for 1 minute, and the aqueous solution was drawn off and discarded. Ten ml of 5 percent HNO_3 then was added to the funnel and the bottom layer was drained off. This solution was analyzed for lead and cadmium using a Varian model 63 carbon rod atomizer on a Jarrell-Ash model 82-360 spectrophotometer. The limits of quntification were 0.1 ppm for lead and 0.05 ppm for cadmium on a wet-weight basis.

ARSENIC AND SELENIUM ANALYSES

A 1-g aliquot for arsenic and selenium analysis was dried in a microwave oven for 5 minutes and ignited in a combustion flask with 20 ml of 25 percent HCl for arsenic analysis or a 1:1 mixture of 50 percent HCl and 25 percent H_2SO_4 for selenium analysis.

For arsenic, the solution was transferred to a 100-ml flask and 2 ml of 40 percent hydroxylamine hydrochloride was added. After 15 minutes, 1 ml 6 percent potassium iodide was added to the flask, the flask was allowed to stand for another 15 minutes, and 2 ml 40 percent $SnCl_2$ was added. After stirring, 1 g of 200-400-mesh zinc in a slurry of water was added. The resulting arsine was swept with helium into the burner of a Perkin-Elmer model 303 spectrophotometer. The limit of quantification for arsenic was 0.05 ppm on a wet-weight basis.

For selenium, 10 ml of the combustion flask solution was transferred to a flask and 30 ml of the 1:1 aqueous acid solution with 1 ml $SnCl_2$ was added. Two g 20-mesh zinc was added to the flask and stirred for 15 seconds. The resulting hydrogen selenide was swept into the burner of a Perkin-Elmer model 303 spectrophotometer. The limit of

TABLE 1. *Residues of mercury, lead, cadmium, arsenic, and selenium in starlings, continental United States—1973*

State	City or County	Site Number	Type of Site[1]	Residues, ppm wet weight				
				Mercury	Lead	Cadmium	Arsenic	Selenium
Alabama	Mobile	35	U	0.07	0.75	<0.05	0.18	0.40
Arizona	Phoenix	15	R	<0.01	0.10	0.05	0.05	0.44
Arkansas	Stuttgart	33	R	0.03	2.40	<0.05	0.12	0.34
California	Bakersfield	9	U	<0.01	0.50	0.05	0.09	0.38
	Los Angeles	10	U	<0.01	0.80	<0.05	0.05	0.38
	Sacramento	7	U	0.06	<0.10	<0.05	<0.05	0.32
Colorado	Brighton	13	R	<0.01	<0.10	0.12	<0.05	0.36
Connecticut	Conn. River Valley	51	R	<0.01	1.80	<0.05	0.12	0.56
Florida	Gainesville	47	R	<0.01	0.65	0.05	0.12	0.10
Georgia	Atlanta	46	U	0.01	1.70	0.09	0.06	0.38
Idaho	Boise	5	R	<0.01	<0.10	0.08	0.09	0.24
Illinois	Chicago	27	U	<0.01	1.00	<0.05	0.07	0.36
Indiana	Evansville	30	R	<0.01	1.20	0.07	0.12	0.72
	Gary	28	U	0.01	1.10	0.08	0.07	0.80
Iowa	Des Moines	29	U	<0.01	0.55	<0.05	0.08	0.20
Kansas	Garden City	20[2]	R	0.01	0.55	0.07	0.20	0.60
Louisiana	Baton Rouge	36	R	0.02	0.65	0.09	0.22	0.60
Maine	Gray	48	R	<0.01	0.35	0.10	0.07	0.34
Maryland	Patuxent	41	U	<0.01	1.10	0.08	0.06	0.36
	Annapolis	42	U	<0.01	1.30	0.05	0.13	0.17
Massachusetts	Quincy	50	U	<0.01	0.45	<0.05	0.19	0.28
Michigan	Lansing	26	U	<0.01	0.80	0.06	0.17	0.32
Minnesota	Twin Cities	24[3]	U	<0.01	1.20	0.05	0.17	0.44
Mississippi	Starkville	34	R	<0.01	0.60	<0.05	0.10	0.48
Missouri	Malden	31	R	0.01	0.60	0.13	0.50	0.48
Nebraska	North Platte	19	R	0.01	0.50	0.05	<0.05	0.36
Nevada	McGill	8	R	<0.01	<0.10	<0.05	0.14	0.38
	Reno	6	R	0.20	<0.10	<0.05	0.18	0.80
New Jersey	New Brunswick	38	U	<0.01	3.20	0.06	0.15	0.34
New Mexico	Carlsbad	16	R	<0.01	0.25	<0.05	0.19	0.48
	Farmington	14	R	<0.01	1.30	0.05	<0.05	0.60
New York	Albany	49	U	<0.01	0.65	0.08	0.21	0.20
	Jamestown	37	U	<0.01	1.90	<0.05	0.08	0.32
North Carolina	Raleigh	45	U	<0.01	1.20	0.05	<0.05	0.24
North Dakota	Bismarck	17[4]	R	0.01	0.25	0.09	0.28	0.48
Ohio	Columbus	40	R	0.06	1.80	0.05	<0.05	0.68
Oklahoma	Tishomingo	21	R	<0.01	1.30	<0.05	<0.05	0.60
Oregon	Corvallis	4	R	0.05	<0.10	0.06	0.27	0.38
	Wilsonville	3	R	0.05	0.55	0.07	0.10	0.31
Pennsylvania	Pittsburgh	39	U	<0.01	1.30	0.11	1.40	0.36
South Dakota	Pierre	18[5]	R	0.13	0.14	<0.05	0.52	0.84
Tennessee	Nashville	32	U	<0.01	1.10	0.05	0.24	0.48
Texas	Hillsboro	22	R	0.01	0.80	<0.05	<0.05	0.44
	San Antonio	23	U	<0.01	1.00	<0.05	0.11	0.84
Utah	Salt Lake City	12[5]	R	0.04	0.85	0.20	0.26	0.36
Virginia	Blacksburg	44	R	0.03	0.95	0.05	0.07	0.44
Washington	Spokane	1	R	<0.01	1.30	<0.05	0.25	0.27
	Yakima	2	R	0.03	<0.10	0.05	0.07	1.10
West Virginia	Elkins	43	R	0.01	0.75	0.07	0.11	0.27
Wisconsin	Portage	25	U	0.03	1.20	0.06	0.07	0.72
Wyoming	Worland	11[4]	R	<0.01	0.50	0.05	<0.05	0.68

[1] R = rural areas; U = urban, suburban areas.
[2] Sample size = 7.
[3] Sample size = 8.
[4] Sample size = 3.
[5] Sample size = 9.

quantification for selenium was 0.05 ppm on a wet-weight basis.

Results and Discussion

Table 1 lists the residues of mercury, lead, cadmium, arsenic, and selenium in starlings by collection site for 1973. Sites are designated either urban or rural. Since some starlings are migratory, caution is advised in making interpretations on a statewide basis. In addition, residue levels do not necessarily reflect year-round levels, because birds were collected in the fall.

MERCURY

As in earlier surveys (*2,3*) mercury levels were uniformly low in starling pools, ranging from <0.01 to 0.20 ppm. Thirty-eight samples, 75 percent, had mercury residues ≤0.01 ppm, and only five samples exceeded 0.05 ppm. Analysis of variance between residues in the 1971 and 1973 collections indicated an overall decline ($P<0.01$) in mercury residues (Table 2). The 1973 residues were down by 68 percent. The banning of mercuric fungicides for treatment of seeds in 1970-71 may be a major reason for this decline; however, as Baskett (*1*) points out, many of the industrial sources of mercury pollution have been eliminated or greatly reduced in recent years. There was no difference between levels of mercury in starlings from urban and rural areas in 1973 (Table 3).

LEAD

Lead residues were present in all samples, ranging from <0.10 to 3.20 ppm (Table 1). Twenty (39 percent) of the samples had residues of 1.00 ppm or greater but there

TABLE 2. *Arithmetic means, ranges, and geometric means of metals and selenium in starlings, 1971 and 1973*

Element	Year	No. Pools	$\bar{X} \pm$ SE	Range	Geom. $\bar{X}$
Mercury	1971	50	0.063[1] ± 0.015	0.01-0.62	0.032
	1973	51	0.020 ± 0.005	<0.01-0.20	0.010
Lead	1971	50	1.310[2] ± 0.190	0.12-6.60	0.840
	1973	51	0.850 ± 0.091	<0.10-3.20	0.550
Cadmium	1971	50	0.048 ± 0.006	0.05-0.24	0.038
	1973	51	0.056 ± 0.005	<0.05-0.20	0.048
Arsenic	1971	50	0.019[3] ± 0.005	0.01-0.21	0.014
	1973	51	0.156 ± 0.029	<0.05-1.40	0.102
Selenium	1971		No analysis		
	1973	51	0.451 ± 0.028	0.10-1.10	0.410

[1] Means for the two years significantly different: $P < 0.01$.
[2] Means for the two years significantly different: $P < 0.05$.
[3] Means for the two years significantly different: $P < 0.001$.

TABLE 3. *Comparison of metal and selenium residues in starlings from urban and rural sites, 1973*

Element	Site	No. Pools	$\bar{X} \pm$ SE	Range	Geom. $\bar{X}$
Mercury	Urban	21	0.012 ± 0.004	<0.01-0.07	0.007
	Rural	30	0.025 ± 0.007	<0.01-0.20	0.012
Lead	Urban	21	1.088[1] ± 0.140	<0.10-3.20	0.885
	Rural	30	0.681 ± 0.110	<0.10-2.40	0.390
Cadmium	Urban	21	0.042 ± 0.007	<0.05-0.11	0.019
	Rural	30	0.053 ± 0.008	<0.05-0.20	0.023
Arsenic	Urban	21	0.171 ± 0.063	<0.05-1.40	0.085
	Rural	30	0.139 ± 0.024	<0.05-0.52	0.057
Selenium	Urban	21	0.395 ± 0.039	0.17-0.84	0.362
	Rural	30	0.491 ± 0.038	0.10-1.10	0.448

[1] Means for the two areas significantly different: $P < 0.05$.

appeared to be no geographic pattern associated with these higher levels. Those samples with ≥1.00 ppm lead were from widely scattered sites, both urban and rural, throughout the country. There was a significant overall decline ($P<0.05$) of 35 percent in lead residues since 1971 (Table 2). The reason for this apparent decline is not clear. The increased use of lead-free gasoline in automobiles could be a factor, as well as the reduction of lead contamination in industrial effluents. Analytical methods for lead were essentially the same in 1971 and 1973, as were all the residue determinations; therefore, the data for the two periods are comparable. Lead residues in starlings from urban areas were significantly higher than in those from rural areas in 1973 (Table 3). This is expected because of the higher exposure to automotive and industrial contaminants in urban areas (*3*).

CADMIUM

Cadmium residues were detected in all starling samples, ranging from <0.05 to 0.20 ppm (Table 1). Thirty-one (61 percent) of the samples had residues ≤0.05 ppm and only five samples had levels of 0.10 ppm or greater. As reported earlier (*3*) cadmium residues in whole-body samples of starlings were low. Residues would be higher in major accumulator organs, such as kidneys or livers, than in whole bodies. White and Kaiser (*9*) report levels of cadmium in ruddy duck livers up to 1.60 ppm, and White and Stendell found levels up to 10.0 ppm in kidneys of canvasbacks (Residues of Environmental Pollutants in Canvasback Tissues, Eggs, and Food Materials, 1976. D.H. White and R.C. Stendell [*unpublished*], Patuxent Wildlife Research Center, Laurel, Md. 20811). There was no statistical difference between mean levels of cadmium in starlings in 1971 and those in 1973 (Table 2). Also, there was no difference in cadmium residues from urban and rural sites (Table 3).

ARSENIC

Unlike 1971, arsenic residues were present in all starling samples in 1973, ranging from <0.05 to 1.40 ppm (Table 1). Twenty-eight (55 percent) of the samples contained residues of 0.10 ppm or greater. Arsenic residues in 1973 were 88 percent higher ($P<0.001$) than in 1971 (Table 2). This overall increase of residues in starlings may reflect an increase in the use of arsenic containing compounds as insecticides or herbicides on lawns. A comparison of urban and rural sites, however, showed no significant difference in residue accumulations from the two areas (Table 3). Wiersma et al. (*10*) found no difference in arsenic residues in soil from lawn and unkept areas in eight different cities; they attribute arsenic residues in the environment mainly to industrial or combustion sources rather than to pesticidal contamination. These data support that hypothesis.

SELENIUM

Selenium was included in the starling analyses for the first time in 1973. Selenium is a necessary dietary element for many animals, including mammals and birds (*5*), but is very toxic in excessive amounts. Sources of environmental contamination by selenium include copper and lead smelting, combustion of fossil fuels, wastes from paper mills, and many other industrial processes (*6*). Selenium residues were present in all starling samples and ranged from 0.10 to 1.10 ppm (Table 1). There was no difference between residues in urban and rural areas (Table 3). These data indicate that selenium is widespread in the environment and is readily available to birds.

Conclusions

Nationwide, residues of mercury and lead have declined significantly in starlings since 1971. On the other hand, arsenic residues have shown a pronounced increase. Selenium, analyzed for the first time, was found in all starling samples, indicating that this element is widespread throughout the country. These data suggest that starlings can serve as indicators of environmental levels of metals, as do starlings and waterfowl for organochlorines (*7,8*), and thus provide information on residue trends over an extended period of time.

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Residues of Organochlorines and Heavy Metals in Tissues and Eggs of Brown Pelicans, 1969-73

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ABSTRACT

Shells of brown pelican (Pelecanus occidentalis) *eggs collected in South Carolina from 1969 through 1973 were significantly thinner than shells of those collected before 1947. Residues of 10 organochlorine pollutants and 10 heavy metals were found in these eggs. Total organochlorine residues were apparently magnified 23 times from fish to pelican eggs, but interpretation of biomagnification was complicated by the migratory habits of both the pelicans and their chief prey fish.*

Residues of organochlorine pollutants and heavy metals were also found in tissues of brown pelicans. Dieldrin was probably involved in the death of a pelican that exhibited myocardial necrosis. Other pelicans died from gunshot wounds, various diseases, or unknown causes.

From 1969 through 1973, there was a significant decline in residues of p,p'-*DDE,* p,p'-*TDE,* p,p'-*DDT, and dieldrin in eggs of the brown pelican in South Carolina, but the rate of decline was different for each pollutant. PCB's peaked in 1972 and then declined in 1973 to the lowest level in 5 years. In 1973, the first time in many years, South Carolina brown pelicans reproduced very well. The excellent reproductivity seemed related to lowered organochlorine residues and favorable tides, weather, and food supply.*

Introduction

The brown pelican (*Pelecanus occidentalis*) provides a classic example of adverse biological effects caused by certain environmental pollutants. Shells of brown pelican eggs have thinned in all parts of their range in the United States (*1,4,9,24,31*) and in parts of Mexico (*20,24*); reproduction has been adversely affected (*2,10,20*); and a population in South Carolina has been substantially reduced (*3,5*). There is speculation that pollution was involved in the extirpation of a population of brown pelicans in Louisiana (*2,21*). In previous studies, authors demonstrated that DDE was the agent principally responsible for eggshell thinning (*5-8*); and that DDE, and to a lesser extent dieldrin, were responsible for limited reproduction and probably the population decline in South Carolina (*10*). In the last several years, however, the status of the brown pelican has improved in several areas of its geographic range (*2,9*). This paper describes the biological significance of certain pollutants in eggs and tissues of brown pelicans in South Carolina and discusses the impact of declining residues on these birds. Pertinent residue data from tissues and eggs of Florida pelicans are also included.

PROCEDURES FOR SAMPLING, NECROPSY, AND FIELD STUDY

The authors made brief visits to brown pelican colonies in South Carolina in 1969 and 1970; most of the data were published previously (*5*) as were the data from a study of brown pelicans in Louisiana (*9*). The intensive study in South Carolina was conducted in the spring and summer each year from 1971 through 1973. The nesting colony on Marsh Island, Cape Romain National Wildlife Refuge, received most attention, but authors also studied the only other colony in the State, Deveaux Bank. An annual census was conducted of total nests and fledged young in each colony. Eggs in all stages of incubation, both viable and addled, were collected throughout the nesting season. Collectors attempted to gather eggs in all portions of each colony. Some unbroken, rolled eggs were also collected. It was sometimes possible to salvage contents of cracked or crushed eggs. Eggshells of depredated eggs, hatched eggs, and crushed or cracked eggs were collected. One egg was usually taken from each nest selected for sampling.

On Marsh Island two types of nests were marked to determine nest success; one type included nests with full clutches and the other included nests from which one egg was collected. Marked nests were checked for eggs or young on each visit to the colony; collectors usually made two visits to each colony per week with a maximal stay of

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1 hour per visit. Several dead pelicans and samples of fish, regurgitated by pelicans, were also collected. Colleagues from Florida provided several pelicans that were found dead on the Atlantic Coast near Stuart in 1972 and in Florida Bay in 1973.

Eggs were weighed and measured. The contents of some eggs were removed before freezing and placed in glass bottles which had been rinsed with dilute nitric acid solution, deionized water, hexane, and acetone. Caps were lined with aluminum foil and the bottles were placed in a freezer. If eggs were not opened immediately, they were wrapped in foil, frozen, and later opened while still frozen. A record was made of the stage of development of each egg. Shells were washed thoroughly with tap water and allowed to dry at room temperature. Shell thickness, which includes shell and shell membranes, was measured at three sites on the waist of the egg with a micrometer graduated in units of 0.01 mm; the average of the three measurements was used to represent the thickness of the shell.

Fish samples were taken from pools of several regurgitated boluses found in the South Carolina colonies. Nesting pelicans and their young regurgitate food when they are disturbed; hence authors collected fish that had undergone little digestion.

The pelicans found dead were frozen; the specimens were removed from the freezer several months later, allowed to thaw, and subsequently necropsied to determine cause of death. Tissues for histological study were fixed in 10 percent formalin, embedded in paraffin, sectioned, and stained. The entire brain was removed and placed in a chemically clean glass bottle, and the remaining carcass, except for skin, feet, wings, liver, kidney, and gastrointestinal tract, was wrapped in foil and refrozen. The brains and carcasses were later analyzed for residues of organochlorine pollutants, and some livers were analyzed for heavy metals. The livers of four pelicans shot in 1970 were analyzed for residues of heavy metals.

Analytical Procedures

Analyses for heavy metals in eggs and tissues were conducted by the Environmental Trace Substances Center, Columbia, Mo. (J. R. Vogt, ed., University of Missouri Nuclear Science Group, 1970-71: unpublished reports). Nickel, selenium, arsenic, and chromium were analyzed by neutron activation techniques. Samples were freeze-dried and placed in vials for irradiation. Irradiation conditions and times were: a neutron flux of 4×10^{13} n /cm^2 /sec—5 to 15 minutes for arsenic and 200 hours for chromium; 5×10^{13} n/cm^{-2}/sec^{-1}—30 to 60 minutes for selenium and approximately 20 minutes for nickel. The samples were allowed to undergo radioactive decay for given periods of time following irradiation. Chemical separation of the metal was then conducted, followed by counts of gamma-ray radiation from each sample. The counter was a Packard Model 9012, 1024 channel Pulfe Height analyzer with a Na-I detector. Residues of metals were measured with the 0.32 MeV gamma-ray of ^{51}Cr, the 556 KeV gamma-ray of ^{76}As, the 1.49 MeV gamma-ray of ^{65}Ni, and the 104 KeV gamma-ray of ^{81m}Se.

Samples to be analyzed for copper, zinc, cadmium, lead, and magnesium were wet-ashed with a mixture of nitric and perchloric acids to destroy the organic material and then solubilized in an acidic solution. Lead and cadmium were chelated with ammonium pyrrolidine carbodithionate, and extracted from the aqueous phase into methyl isobutyl ketone (MIBK). The MIBK containing the lead and cadmium complexes was analyzed using a flame atomic absorption (AA) technique. The solubilized samples for copper, magnesium, and zinc analyses were directly aspirated into the AA flame. Absorbance was recorded at the following wave lengths (nm): lead, 283.3; cadmium, 228.8; copper, 324.7; zinc, 213.9; and magnesium, 285.2, using an Instrumentation Laboratories Model 453 AA spectrometer. Samples for mercury analysis were digested with nitric acid. Stannous chloride was added to reduce ionic mercury to elemental mercury, which was then measured photometrically in the vapor phase by AA using a Perkin-Elmer Model 290.

Pelican tissues and the contents of the eggs were analyzed individually for residues of organochlorine pesticides, their metabolites, and polychlorinated biphenyls (PCB's); these analyses were completed at the Patuxent Wildlife Research Center, Laurel, Maryland.

For eggs and pelican tissues collected in 1971, residue analysis was performed as follows: a 10-g sample of the ground carcass, the entire brain, and a 20-g sample of the homogenized egg were mixed separately with anhydrous sodium sulfate in a blendor and extracted for 7 hours with hexane in a Soxhlet apparatus. Extracts were cleaned by acetonitrile partitioning and elution on partly deactivated florisil; half was saved for PCB analysis. For insecticide analysis, residues in the cleaned extract were separated and removed in four fractions from a silica gel thin-layer plate (*30*). Each thin-layer fraction was analyzed by electron-capture gas chromatography (GC) on a column of 3 percent OV-1 or 3.8 percent UCW-98 on Chromosorb WHP. DDT and its metabolites in fractions III or IV were confirmed on a column of 3 percent XE-60 or 3 percent QF-1 on Gas-Chrom Q. PCB's were identified and measured semiquantitatively by thin-layer chromatography (*29*). The average percent recoveries of organochlorine pesticides and their metabolites from spiked bald eagle (*Haliaeetus leucocephalus*) carcasses were: DDE, 95; TDE, 102; DDT, 110; dieldrin, 106; heptachlor epoxide, 112; and *o,p'*-DDT, 107. Residues were not corrected for recovery values.

For eggs and pelican tissues collected in 1972 and 1973, the methodology was modified as described by Cromartie

et al. (*14*). Lipids were removed from the extract by a column chromatography procedure using washed, recalcined, and partly deactivated florisil. An aliquot of the florisil eluate was concentrated and placed on a silicic acid column to separate the pesticides from PCB's. The organochlorine residues were collected in three fractions and analyzed with an electron-capture gas chromatograph equipped with a 4 percent SE-30/6 percent QF-1 column. Using this method, authors were able to detect additional pesticides: toxaphene, *cis*-chlordane and/or *trans*-nonachlor, and *cis*-nonachlor. In 1972 the laboratory did not have a *cis*-nonachlor standard for quantitation, and authors first developed a procedure to estimate toxaphene levels in 1973; a manuscript is being prepared which describes the procedure. DDE was measured by peak height to avoid errors from PCB interference; the other organochlorines were quantitated with a computing integrator and PCB's were estimated by comparing total area of PCB peaks with that of Aroclor 1260. A combined gas chromatograph / mass spectrometer (GC-MS) was used to confirm residues in about 10 percent of the samples. Average percent recoveries from spiked mallard carcass tissues were: DDE, 96; TDE, 103; DDT, 110; dieldrin, 101; heptachlor epoxide, 104; mirex, 106; oxychlordane, 98; *cis*-chlordane, 100; *cis*-nonachlor, 98; HCB, 69; and Aroclor 1254, 101. Residues in the pelican eggs and tissues were not corrected for recovery values. The lower limit of detection for pesticides or their metabolites was 0.01 μ g/g in regurgitated fish and 0.10 μ g/g in other samples; the lower limit for PCB's was 0.05 μ g/g in regurgitated fish and 0.50 μ g/g in other samples.

Results and Discussion

EGGSHELL THICKNESS

The eggshells of South Carolina pelicans were 14 to 17 percent thinner ($P<0.05$) each year from 1969 through 1973 than they had been before 1947 (Table 1). The average annual thicknesses are similar for the 5-year period 1969-73, although the mean thickness in 1971 was significantly greater ($P<0.05$) than that recorded in several other years. Mean thicknesses listed in Table 1 are derived from entire eggs found in the nest.

Authors compared eggshell thickness to stage of embryonic development and to fate of the eggs. Eggshell thickness seemed to increase during incubation, although

TABLE 1. *Eggshell thickness of brown pelican eggs, South Carolina*

Eggshell Thickness, mm[1]					
Pre-1947	1969	1970	1971	1972	1973
0.557± A[2] 0.012(23)	0.463± C 0.006(49)	0.461± C 0.007(38)	0.480± B 0.005(65)	0.470± BC 0.005(67)	0.463± C 0.003(104)

[1]Mean ± standard error; sample size in parentheses.
[2]A significant difference among thickness means ($P<0.05$) is indicated for those means not showing a common letter. Means were separated using the new multiple range test (*16*) with extension for unequal replication (*25*).

TABLE 2. *Eggshell thickness of brown pelican eggs by stage of incubation, South Carolina—1971-73*

Stage of Incubation	Eggshell Thickness, mm[1]	
	Mean ± Standard Error (number)	Range
Freshly laid	0.466± 0.004 (113) B	0.36-0.61
Early development (<2/3)	0.467± 0.003 (169) B	0.37-0.57
Late development (≥2/3)	0.475± 0.007 (37) B	0.40-0.56
Hatched	0.506± 0.006 (19) A	0.46-0.56

[1]See footnotes, Table 1.

TABLE 3. *Eggshell thickness of brown pelican eggs by condition, South Carolina—1971-73*

Condition	Eggshell Thickness, mm[1]	
	Mean ± Standard Error (number)	Range
Hatched	0.506± 0.006 (19) A	0.46-0.56
Stepped on	0.480± 0.018 (6) AB	0.41-0.53
Entire	0.469± 0.002 (236) B	0.36-0.61
Rolled	0.468± 0.015 (11) B	0.38-0.58
Depredated	0.465± 0.009 (17) B	0.42-0.54
Crushed	0.377± 0.015 (40) C	0.13-0.47

[1] See footnotes, Table 1.

Kreitzer (*26*) reported the contrary to be true of Japanese quail (*Coturnix coturnix japonica*). Eggshell thickness is an important factor in the nest life of the egg, and thin-shelled pelican eggs have a shorter nest life than have those with thicker shells. The minimum thickness increased with each stage of incubation; for example, the minimum shell thickness of a hatched egg was 0.46 mm, compared to 0.36 mm in an intact freshly laid egg (Table 2).

Thickness of eggshells also varied with condition of the egg (Table 3). Brown pelican eggs were examined and classified according to six conditions: entire, rolled, depredated, stepped on, crushed, and hatched. Entire eggs were those found intact in the nest; rolled eggs were entire eggs which had been removed from the nest, apparently by the parent. Most rolled eggs were freshly laid and were noted early in the nesting season; on April 5, 1973, over 100 rolled eggs were observed in a colony containing 400 nests. It is probable that pelicans deliberately rolled their eggs out of the nest, especially during periods of unseasonably cold weather. Pelicans desert their nests in the Florida Keys in apparent response to unseasonably cold weather (Alexander Sprunt IV, National Audobon Society, 1969: personal communication), and some deserted their nests at Pelican Island, Fla., in response to a food shortage (*19*).

Most of the depredated eggs had probably been rolled from nests by pelicans before they were depredated by laughing gulls (*Larus atricilla*). No laughing gulls were observed depredating eggs in active pelican nests, and it appears that these gulls take few viable eggs. The herring gull (*Larus argentatus*) and the ring-billed gull (*Larus delawarensis*) may be more efficient egg predators, but

TABLE 4. *Residues of organochlorine pollutants in eggs of brown pelicans, South Carolina—1971*

Residues, μg/g fresh wet weight						
DDE	TDE	DDT	Dieldrin	Heptachlor Epoxide	Mirex	PCB's
Marsh Island						
1.93	0.20	0.18	0.34	—	—	4.1
2.15	0.23	0.14	0.57	—	—	4.9
6.05	1.04	0.79	0.92	—	—	9.9
1.71	0.37	0.34	0.31	—	—	3.8
3.97	0.77	0.47	0.84	—	—	5.4
2.56	0.74	0.13	0.71	—	—	3.6
3.87	0.80	0.42	1.11	—	0.31	4.7
3.44	0.70	0.30	0.34	—	—	7.4
1.93	0.57	0.37	0.58	—	—	6.5
2.87	0.44	0.41	0.21	—	—	5.4
1.82	0.26	0.18	0.39	—	—	4.5
2.46	0.47	0.52	0.43	0.17	—	36.5
1.39	0.27	0.19	0.19	—	—	3.0
1.90	0.71	0.18	0.54	—	—	17.3
3.99	1.04	—	0.83	—	—	9.2
1.30	0.48	—	0.33	—	—	5.3
3.47	0.80	0.17	0.81	—	—	20.1
2.26	0.21	0.22	—	—	—	19.7
2.49	0.44	0.11	0.47	—	—	3.9
1.12	0.20	0.16	0.31	—	—	1.5
1.20	0.48	—	0.24	—	—	2.4
1.96	0.54	—	0.52	—	—	1.9
1.94	0.39	—	0.32	—	—	2.6
2.25	0.37	0.13	0.42	—	—	18.6
2.23	0.41	0.23	0.56	—	—	5.8
2.46	0.52	0.28	0.49	—	—	3.9
4.55	0.53	0.89	1.02	—	—	19.8
2.77	0.47	0.30	0.62	—	—	6.2
2.64	0.64	—	0.37	—	—	5.7
1.77	0.25	—	0.36	—	—	3.4
3.59	0.47	0.30	0.72	—	—	9.7
2.66	0.37	0.19	0.26	—	—	3.8
1.96	0.43	—	0.42	—	—	5.9
2.85	0.55	0.21	0.32	—	—	3.6
2.37	0.83	—	0.28	—	—	3.6
2.26	0.61	0.42	0.29	—	—	3.9
3.09	0.31	—	0.70	—	—	8.0
3.60	0.96	—	0.66	—	—	7.3
2.95	0.46	—	0.57	—	—	17.9
2.92	0.68	0.31	0.77	—	—	3.8
2.15	0.35	0.20	0.61	—	—	5.9
3.57	0.76	0.23	0.43	—	—	7.1
2.97	0.49	0.39	0.45	—	—	5.9
2.68	0.51	—	0.92	—	—	9.2
GM 2.48	0.48	0.16	0.45			6.02
CL 2.23-2.76	0.42-0.55	0.12-0.21	0.38-0.54			4.89-7.42
Range 1.12-6.05	0.20-1.04	ND-0.89	0.20-1.02	ND-0.17	ND-0.31	1.5-36.5
Deveaux Bank						
1.25	0.18	—	0.21	—	—	5.8
1.60	0.22	0.14	0.21	—	—	3.3
2.29	0.39	0.17	0.38	—	—	9.6
3.02	0.34	0.21	0.61	—	—	5.8
1.42	0.40	0.35	0.25	—	—	2.8
2.11	0.50	—	0.49	—	—	4.5
2.34	0.48	—	0.53	—	—	1.8
3.70	0.75	—	0.55	—	—	7.2
3.30	0.86	—	0.61	—	—	9.2
1.27	0.35	—	0.20	—	—	3.6
2.37	0.40	0.21	0.46	—	—	5.7
2.10	0.57	—	0.80	0.14	—	5.3
1.69	0.38	—	0.34	—	—	9.2
3.19	0.44	—	0.64	—	—	9.1
4.40	0.56	0.37	0.87	0.10	—	26.9
2.19	0.70	0.23	0.31	—	—	5.5
3.71	0.77	—	0.79	—	—	9.4
2.98	0.82	0.16	0.86	—	—	29.8
3.06	0.58	0.13	0.56	—	—	9.5
3.95	1.01	—	0.59	—	—	18.4
3.21	0.27	—	0.54	—	—	26.8
GM 2.46	0.48	0.09	0.47			7.56
CL 2.07-2.93	0.39-0.59	0.06-0.13	0.38-0.58			5.38-10.63
Range 1.25-4.40	0.18-1.01	ND-0.37	0.20-0.87			1.8-29.8
Marsh Island and Deveaux Bank						
GM 2.48	0.48	0.13	0.46			6.48
CL 2.27-2.71	0.43-0.53	0.11-0.17	0.40-0.52			5.44-7.73
Range 1.12-6.05	0.18-1.04	ND-0.89	0.20-1.02	ND-0.17	ND-0.31	1.5-36.5

NOTES: ND or — = no residue detected.
GM = geometric mean.
CL = 95% confidence limits.

TABLE 5. *Residues of organochlorine pollutants in eggs of brown pelicans, South Carolina—1972*

Residues, μg/g fresh wet weight							
DDE	TDE	DDT	Dieldrin	Heptachlor Epoxide	Mirex	*Cis*-Chlordane[1]	PCB's
Marsh Island							
2.33	0.26	—	—	—	—	—	6.0
2.05	0.18	0.24	0.17	—	—	—	3.9
2.71	0.19	0.25	0.17	—	—	0.10	4.4
1.83	0.12	0.10	0.32	—	0.11	0.10	3.2
2.47	0.11	0.10	0.15	—	—	—	4.4
2.30	029	0.15	0.37	—	0.15	0.10	3.5
2.42	0.42	0.15	0.40	—	0.11	0.10	6.3
3.75	0.63	0.25	0.63	—	0.16	0.16	7.6
4.48	0.10	0.25	—	—	0.26	—	6.4
1.20	0.16	—	0.28	—	0.11	—	3.9
1.90	0.15	0.12	0.52	—	0.20	0.10	6.0
2.33	0.49	0.27	0.59	—	0.14	—	6.0
2.34	0.22	0.17	0.39	—	0.12	0.10	5.
3.97	0.43	0.18	0.61	—	0.18	0.15	9.2
3.00	0.22	0.16	0.46	—	0.11	0.13	5.2
3.08	0.34	0.22	0.68	—	—	0.17	5.4
3.50	0.50	0.28	0.74	—	0.19	0.19	6.8
2.85	0.42	0.21	0.45	—	—	0.15	5.3
3.46	0.38	0.19	0.54	—	0.17	0.16	8.4
2.57	0.23	0.12	0.41	—	—	0.11	5.8
2.15	0.32	0.32	0.56	—	—	—	2.6
2.66	0.30	0.18	0.64	—	0.17	0.10	6.5
5.24	0.61	0.45	0.77	—	0.26	0.25	16.7
2.18	0.49	—	0.29	—	—	—	6.0
2.21	0.18	0.18	0.45	—	—	—	5.8
3.95	0.67	0.39	0.64	—	0.23	0.20	8.4
3.99	0.55	0.30	0.52	—	—	0.17	9.2
3.61	0.34	0.34	0.32	—	0.11	—	6.3
7.04	1.23	0.42	0.38	—	0.13	—	23.6
2.37	0.61	0.13	0.35	—	—	—	5.1
1.46	0.22	0.14	0.28	—	0.14	—	4.9
1.58	0.19	—	0.19	—	0.19	—	3.9
2.25	0.38	—	0.32	—	—	0.11	9.0
2.88	0.60	—	0.50	—	—	0.22	8.6
1.76	0.17	—	0.29	—	—	—	3.8
3.49	0.27	0.27	0.75	—	—	0.13	7.8
1.56	0.29	0.32	0.19	—	—	0.13	5.7
3.99	0.39	0.33	0.99	—	—	0.13	8.3
4.37	0.83	—	0.64	—	—	0.22	10.4
3.32	0.70	0.18	0.58	—	—	0.18	9.0
3.52	0.29	0.15	0.50	—	—	—	7.7
5.35	0.46	0.38	1.11	—	0.16	0.19	16.1
4.14	0.36	0.25	0.71	—	—	0.11	9.8
6.61	0.66	0.37	0.75	—	0.11	0.16	14.5
8.48	0.95	0.39	0.40	—	0.19	0.34	32.3
6.49	1.21	—	0.89	—	0.11	0.24	15.0
3.08	0.20	0.13	0.48	—	0.10	0.10	6.9
3.92	0.33	0.15	0.44	—	0.14	—	9.4
4.12	0.38	0.22	0.75	—	0.15	0.14	6.2
GM 3.02	0.34	0.17	0.41				6.98
CL 2.68-3.42	0.29-0.41	0.14-0.20	0.34-0.50				6.05-8.05
Range 1.20-8.48	0.10-1.23	ND-0.45	ND-1.11	ND	ND-0.26	ND-0.34	2.6-32.3
Deveaux Bank							
4.17	1.05	0.57	1.32	0.13	—	0.17	11.6
8.38	1.92	0.77	1.76	0.53	0.31	0.49	14.6
1.95	0.46	0.22	0.43	—	0.10	—	3.8
1.51	0.32	0.20	0.29	—	0.11	0.11	4.6
3.06	0.26	0.13	0.26	—	0.15	—	7.5
4.35	0.36	0.22	0.41	—	0.21	—	8.1
2.54	0.21	0.12	0.31	—	0.16	—	7.6
4.12	0.35	0.10	0.39	—	0.13	0.10	13.3
1.48	0.14	—	0.23	—	—	—	5.2
3.78	0.45	0.28	0.60	—	—	0.15	8.1
1.47	0.13	—	0.26	—	—	—	5.8
4.55	0.47	—	0.80	—	0.16	0.17	11.7
8.06	0.43	0.17	0.39	—	0.46	0.25	24.5
0.74	0.28	0.31	0.68	—	0.12	0.12	10.3
2.27	0.27	0.13	0.73	—	—	0.25	6.2
3.47	0.84	—	0.42	—	—	0.13	7.3
2.64	0.23	0.23	0.54	—	—	—	7.3
5.39	1.44	—	0.93	—	0.16	0.42	26.5
6.85	0.70	0.38	1.15	—	0.41	0.24	14.3
2.86	0.40	—	0.61	0.11	0.15	0.14	7.4
1.28	0.17	—	0.20	—	—	—	6.1
3.35	0.29	0.11	0.64	—	0.12	0.11	7.0
4.55	0.70	—	1.21	—	0.15	0.26	10.0

(*Continued next page*)

TABLE 5. (cont'd.). *Residues of organochlorine pollutants in eggs of brown pelicans, South Carolina*—1972

Residues, μg/g fresh wet weight							
DDE	TDE	DDT	Dieldrin	Heptachlor Epoxide	Mirex	*Cis*-Chlordane[1]	PCB's
GM 3.05	0.40	0.13	0.53				8.79
CL 2.34-3.98	0.30-0.54	0.09-0.19	0.41-0.69				7.81-9.90
Range 0.74-8.38	0.13-1.92	ND-0.77	0.20-1.76	ND-0.53	ND-0.46	ND-0.49	3.8-26.5
Marsh Island and Deveaux Bank							
GM 3.03	0.36	0.15	0.45				7.51
CL 2.70-3.40	0.31-0.42	0.13-0.18	0.39-0.52				6.68-8.46
Range 0.74-8.48	0.10-1.92	ND-0.77	ND-1.76	ND-0.53	ND-0.46	ND-0.49	2.6-32.3

NOTE: ND or — = no residue detected.
GM = geometric mean.
CL = 95 percent confidence limits.
[1]*Cis*-chlordane and/or *trans*-nonachlor.

the small numbers of immature gulls present during the pelican nesting season take few eggs.

Eggs classified as stepped on are those that authors observed the parent stepping on and crushing when taking flight. Some such eggs were well advanced in the incubation period, but all shells were thinner than the pre-1947 mean listed by Anderson and Hickey (*1*).

Crushed eggs included those that were apparently destroyed by weight stress of the parent during normal incubation; nearly all were freshly laid. Crushed eggs were discovered throughout the nesting season, but most were found early in the season. Some extremely thin eggs were essentially little more than shell membranes; the minimum thickness of a crushed egg was 0.13 mm. Shells of extremely thin-shelled eggs showed interesting variations: the thin shells of eggs in one clutch were light brown instead of the usual white color; in another clutch, shells had lumps of soft calcium carbonate loosely adhering to the shell membrane; and fragile shells of eggs in a third clutch had prominent pimples. It was impossible to measure shell thickness of some eggs with abnormal shells. These extremely thin-shelled eggs were crushed immediately after they were laid.

In 1971, few thin eggshells were noted on the initial visit to Marsh Island in mid-May. The greatest incidence of eggs with extremely thin shells was noted on March 31, 1972. The birds had begun laying only a short time before, and at least 10 of the 300 to 400 nests contained thin-shelled, crushed eggs; at least 3 percent of the nests were unproductive due to thin eggshells. Few thin-shelled eggs were found on the first visit to the island colony in early April 1973. Observations of a few marked nests containing one or more crushed or cracked eggs revealed that all of these nests were unsuccessful. Second clutches in some of these nests had eggs with thicker shells, but authors could not verify that the same female had laid both clutches.

Thickness of eggshells was directly related to the fate of the egg (Table 3). Hatched eggs had significantly thicker shells ($P<0.05$) than had the other five types of eggs except for those that were stepped on. Eggshells of crushed eggs were significantly thinner ($P<0.05$) than were shells of other types of eggs. Shells of entire eggs were considerably thinner ($P<0.05$) than those of hatched eggs and considerably thicker ($P<0.05$) than those of crushed eggs.

RESIDUES

Residues of 10 organochlorines were identified in eggs of brown pelicans (Tables 4-6). Total organochlorine residues in pelican eggs averaged 8.59 μg/g; PCB's and DDE comprised the bulk of these residues. Residues of organochlorines in eggs followed the same pattern in the two colonies; that is, mean residues in a given year were almost the same in each colony; there was much variation in residues of each of the organochlorines in each colony; and there was a general decline from 1969 to 1973 in residues in each colony.

Eleven of the rolled eggs collected in 1973 were analyzed for residues of organochlorines. Mean residues in rolled eggs were essentially the same as those in entire eggs that were collected from nests (Tables 6,7).

Table 8 itemizes residues detected in 13 pelicans which were found dead. Residues in tissues and eggs of brown pelicans provide evidence that the Atlantic Coast of Florida is more heavily contaminated with the organochlorines considered in this study than either the Gulf Coast or Florida Bay. Residues in tissues of pelicans found dead on the Atlantic Coast of Florida in 1972 were several times higher than those in tissues of pelicans found dead in Florida Bay in 1973. The same relationship seemed true of residues in tissues of pelicans shot in the two areas in 1970 (*5*). Pelican eggs collected in 1969 from the Florida Atlantic Coast colonies contained higher organochlorine residues than did those collected either in Florida Bay or on the Gulf Coast (*5*). Residues in pelican tissues were generally low, especially in young found dead. This substantiates earlier findings that prefledgling birds have lower residues than have older birds (*5*).

TABLE 6. *Residues of organochlorine pollutants in eggs of brown pelicans, South Carolina—1973*

Residues, µg/g fresh wet weight									
DDE	TDE	DDT	Dieldrin	Heptachlor Epoxide	Mirex	*Cis*-chlordane[1]	*Cis*-nonachlor	Toxaphene	PCB's
Marsh Island									
2.20	0.12	0.17	0.44	—	0.13	0.17	0.13	0.54	4.2
2.04	0.37	0.20	0.32	—	—	0.24	0.10	0.29	3.9
1.83	0.21	0.16	0.44	—	—	0.23	—	0.29	4.1
1.33	—	0.14	0.27	—	—	0.16	—	0.39	3.2
1.31	—	0.10	0.22	—	—	0.11	—	0.13	3.5
1.57	0.22	0.18	0.44	—	0.11	0.23	0.11	0.52	3.7
3.23	0.60	0.35	0.37	—	—	0.32	0.13	0.42	5.5
1.34	0.21	0.23	0.40	—	0.16	—	0.35	2.5	
2.37	0.19	0.24	0.38	—	—	0.25	0.12	0.45	4.0
2.28	0.13	0.15	0.45	—	0.12	0.19	0.12	0.40	3.5
2.75	0.28	0.25	0.40	—	—	0.28	0.12	0.40	5.8
2.66	0.24	0.27	0.53	—	0.17	0.10	0.41	3.9	
1.71	0.61	—	0.27	—	—	0.21	—	0.16	1.7
2.50	0.20	0.18	0.39	—	0.12	0.25	0.12	0.43	5.2
1.92	0.12	0.18	0.35	—	0.13	0.24	0.11	0.43	4.8
4.17	0.57	0.34	0.60	—	—	0.36	0.13	0.42	11.2
1.45	0.16	0.20	0.45	—	—	0.19	—	0.34	3.3
2.72	0.27	0.17	0.48	—	—	0.23	0.10	0.27	4.4
2.23	0.14	0.22	0.53	—	0.17	—	0.38	4.3	
2.45	0.48	0.30	0.55	—	—	0.33	0.10	0.33	4.5
1.59	0.19	0.14	0.41	—	—	0.18	—	0.31	4.1
3.70	0.32	0.42	0.94	—	—	0.44	0.22	0.94	9.4
0.65	—	—	0.20	—	—	—	—	0.17	0.91
3.96	0.74	0.58	0.81	—	—	0.40	0.15	0.53	5.8
2.58	0.59	0.42	0.47	—	—	0.33	0.13	0.49	4.2
4.22	0.30	0.54	1.12	—	0.11	0.37	0.21	0.96	12.4
1.85	0.12	0.22	0.33	—	—	0.14	—	0.40	3.1
1.91	0.27	—	0.58	—	—	0.14	0.14	0.40	2.9
1.81	0.14	0.18	0.60	—	—	0.25	0.10	0.42	4.7
1.52	0.14	0.21	0.21	—	—	0.16	0.12	0.43	1.9
1.19	0.13	0.11	0.23	—	—	0.20	—	0.28	1.9
1.02	0.10	0.12	0.16	—	—	—	—	0.24	1.7
2.73	0.14	0.25	0.35	—	0.12	0.27	0.15	0.57	6.4
1.49	0.18	0.14	0.25	—	—	0.28	0.11	0.35	3.5
3.27	0.58	0.28	0.50	0.16	—	0.50	0.21	0.38	4.0
2.00	0.22	0.22	0.35	—	—	0.23	0.12	0.58	4.5
2.11	0.30	0.28	0.24	—	—	0.33	0.13	0.48	5.8
1.97	0.24	0.14	0.27	—	—	0.23	0.12	0.39	4.4
1.98	0.26	0.11	0.41	—	—	0.26	—	0.25	6.5
1.88	0.38	0.13	0.40	0.10	—	0.30	0.13	0.64	3.8
1.34	0.55	0.35	0.43	—	—	0.35	0.11	0.35	3.3
2.30	—	—	0.38	—	—	0.25	0.14	0.40	5.3
1.50	0.18	—	0.20	—	—	0.25	—	0.25	4.3
2.20	0.30	0.24	0.28	—	—	0.28	0.13	0.30	4.8
3.02	0.55	0.30	0.50	0.13	—	0.65	0.22	0.78	8.8
3.25	0.30	0.25	0.43	0.12	—	0.43	0.16	0.45	7.3
3.02	0.60	0.33	0.55	—	—	0.38	0.13	0.25	6.5
2.77	0.22	0.24	0.38	—	—	0.21	0.12	0.30	4.5
2.38	0.20	0.31	0.26	—	—	0.31	0.14	0.48	5.2
2.96	0.39	0.32	0.67	—	—	0.39	0.14	0.49	8.6
3.12	0.20	0.43	0.94	0.13	—	0.36	0.20	0.88	11.0
1.52	0.14	0.17	0.16	—	—	0.16	—	0.34	3.6
3.25	0.25	0.38	0.85	—	—	0.33	0.17	0.72	7.5
1.66	0.12	—	0.49	—	—	0.11	0.15	0.20	7.2
4.08	0.46	0.61	1.15	0.12	—	0.43	0.20	0.97	7.6
3.44	0.23	0.32	1.06	0.11	—	0.44	0.17	0.71	11.3
5.15	0.49	0.47	0.98	0.13	—	0.56	0.20	0.66	13.7
8.60	0.69	0.76	1.65	0.19	—	0.84	0.24	0.91	18.5
4.97	0.42	0.50	1.30	0.10	—	0.40	0.17	0.85	11.0
1.63	—	—	0.49	—	—	0.14	—	0.37	9.3
1.67	—	—	0.47	—	—	0.14	—	0.29	5.9
0.74	—	—	0.23	—	—	0.10	—	0.25	2.0
0.99	—	—	0.23	—	—	—	—	0.17	2.1
2.21	0.15	0.15	0.63	—	—	0.22	0.11	0.48	8.3
0.90	—	—	0.25	—	—	—	—	0.23	3.0
2.40	0.23	0.17	0.35	—	—	0.18	0.10	0.33	7.0
2.95	0.39	—	0.66	—	—	0.25	0.17	0.34	8.6
GM 2.16	0.21	0.18	0.43			0.23	0.10	0.40	4.80
CL 1.93-2.42	0.17-0.25	0.15-0.22	0.38-0.49			0.20-0.27	0.09-0.12	0.36-0.44	4.21-5.53
Range 0.65-8.60	ND-0.74	ND-0.76	0.16-1.65	ND-0.19	ND-0.13	ND-0.84	ND-0.22	0.13-0.97	0.91-18.5
Deveaux Bank									
2.39	0.32	0.29	0.83	0.13	—	0.54	0.20	0.66	5.8
1.72	0.12	0.21	0.59	—	—	0.14	0.10	0.56	4.0
1.43	—	0.14	0.47	—	—	0.16	0.11	0.49	3.2
0.82	—	—	0.25	—	—	—	—	0.23	5.0
3.26	0.22	0.48	0.54	—	—	0.19	0.15	0.54	4.6
2.03	0.14	0.25	0.57	—	—	0.16	0.11	0.55	3.9
3.44	0.29	0.34	0.69	—	—	0.27	0.23	0.79	2.9

(*Continued next page*)

TABLE 6 (cont'd.). *Residues of organochlorine pollutants in eggs of brown pelicans, South Carolina—1973*

Residues, µg/g fresh wet weight									
DDE	TDE	DDT	Dieldrin	Heptachlor Epoxide	Mirex	*Cis*-chlordane[1]	*Cis*-nonachlor	Toxaphene	PCB's
Deveaux Bank									
0.88	—	—	0.24	—	—	—	—	0.28	1.1
1.43	0.19	0.25	0.63	—	—	0.20	—	0.38	3.8
1.10	—	—	0.33	—	—	—	—	0.22	1.4
1.01	—	—	0.38	—	—	0.14	—	0.28	2.2
2.18	0.19	0.29	0.62	—	—	0.29	0.13	0.60	4.5
2.46	0.23	0.42	0.89	—	—	0.25	0.14	0.76	6.2
1.58	0.13	0.13	0.37	—	—	0.22	0.10	0.30	3.5
2.32	0.33	0.28	0.42	—	—	0.15	—	0.44	2.3
2.20	0.25	0.28	0.39	—	—	0.23	0.10	0.48	4.4
1.27	—	—	0.76	—	—	0.13	—	0.33	2.4
1.54	0.23	0.23	0.37	—	—	0.27	0.13	0.42	3.7
2.32	0.34	0.30	0.40	—	—	0.14	0.11	0.53	3.6
1.82	0.23	0.17	0.41	—	—	0.21	0.10	0.29	4.1
3.68	0.20	0.10	0.50	—	—	0.24	0.14	0.43	12.1
2.69	0.27	0.12	0.61	0.25	—	0.54	0.20	0.25	13.7
3.87	0.21	0.23	0.80	0.21	—	0.44	0.22	0.60	15.2
2.97	0.19	0.27	0.67	—	—	0.19	0.11	0.52	5.9
3.01	0.18	0.28	0.68	—	—	0.19	0.11	0.50	5.5
3.37	0.20	0.31	0.63	—	—	0.19	0.12	0.58	8.4
0.96	—	—	0.29	—	—	—	—	0.23	3.1
1.40	0.13	0.13	0.40	—	—	0.20	—	0.27	4.0
1.31	0.31	0.21	0.69	0.12	—	0.33	0.17	0.58	7.9
2.14	0.33	—	0.51	—	—	0.17	0.14	0.24	5.5
1.61	0.34	—	0.41	—	—	0.24	0.14	0.15	6.2
4.12	0.61	0.36	0.73	—	—	0.36	0.12	0.36	7.3
1.55	0.12	—	0.41	0.13	—	0.20	0.11	0.54	6.1
1.29	—	—	0.26	—	—	—	—	0.26	3.1
3.01	0.30	0.22	0.53	—	—	0.18	0.12	0.48	5.5
4.98	0.30	0.28	0.93	—	—	0.53	0.25	0.53	19.0
1.59	0.15	0.12	0.50	—	—	0.14	—	0.31	3.6
GM 1.97	0.16	0.15	0.50			0.23	0.10	0.40	4.62
CL 1.69-2.30	0.13-0.21	0.12-0.20	0.44-0.57			0.20-0.27	0.09-0.11	0.35-0.46	3.78-5.64
Range 0.82-4.98	ND-0.61	ND-0.48	0.24-0.93	ND-0.25	ND	ND-0.54	ND-0.25	0.15-0.79	1.1-19.0
Marsh Island and Deveaux Bank									
GM 2.09	0.19	0.17	0.45			0.21	0.10	0.40	4.75
CL 1.91-2.29	0.17-0.22	0.15-0.20	0.41-0.50			0.19-0.24	0.09-0.11	0.37-0.43	4.25-5.31
Range 0.65-8.6	ND-0.74	ND-0.76	0.16-1.65	ND-0.25	ND-0.13	ND-0.84	ND-0.25	0.13-0.97	0.91-19.0

NOTE: ND or — = no residue detected.
GM = geometric mean.
CL = 95 percent confidence limits.
[1]*Cis*-chlordane and/or *trans*-nonachlor.

Probable causes of deaths of pelicans are listed in Table 9. The female adult found dead in Georgia had myocardial necrosis, but she was also carrying a level of dieldrin in the brain that corresponds to a diagnostic lethal level (*33*). Residues of lead may produce myocardial necrosis if present at high levels, but the Georgia pelican with this disease carried very low levels of lead in its tissues. A pelican found dead in Florida Bay in 1973 apparently died of a gunshot wound. Most of those found dead in Florida in 1972 probably died of bacterial enteritis. *Clostridium perfringens*, a causative agent of hemorrhagic enteritis, was isolated from the gut of three of the Florida pelicans, but it was not determined whether the isolates were toxigenic. Recently, hemorrhagic enteritis in fish-eating birds has been connected with the presence of *Edwardisella tarda* in the intestinal tract (*3,4*). Unfortunately, the pelican with enteritis was not tested for *E. tarda*.

Each egg and tissue of the brown pelican that was analyzed contained residues of 10 heavy metals (Tables 10 and 11). However, the significance of these metals to the pelicans is undetermined. Generally, there is a highly significant positive correlation between each organochlorine residue: DDE, TDE, DDT, dieldrin, and PCB's. In contrast, residues of metals are usually negatively correlated with residues of organochlorines (Table 12). Of the 10 metals, 5 demonstrated at least one significant negative correlation ($P<0.05$) with an organochlorine. Significant positive correlations ($P<0.05$) were found in comparing metals to each other: chromium and nickel, nickel and mercury, nickel and lead, and mercury and lead. Zinc, copper, cadmium, arsenic, and chromium had no definite tendencies for significant relationships with the organochlorines or with other metals. In contrast, there was a definite tendency for residues of nickel, selenium, mercury, lead, and magnesium to be negatively correlated with organochlorines and positively correlated with other metals. The significance or validity of these relationships of metals in eggs is difficult to determine because different metals may follow different pathways in the body of the bird. For example, females fed cadmium (*32*) or lead (*17*) laid eggs that contained small amounts of these metals.

TABLE 7. *Residues of organochlorine pollutants in rolled eggs of brown pelicans, South Carolina—1973*

Residues, μg/g fresh wet weight							
DDE	TDE	DDT	Dieldrin	*Cis*-chlordane[1]	*Cis*-nonachlor	Toxaphene	PCB's
2.92	—	—	0.18	—	—	0.14	6.8
1.31	0.16	0.16	0.37	0.16	—	0.25	4.0
1.93	0.18	0.23	0.33	0.14	—	0.30	3.8
2.89	0.55	0.36	0.63	0.29	0.11	0.46	6.0
1.47	0.12	—	0.40	0.14	—	0.30	4.3
2.10	0.25	0.19	0.50	0.19	—	0.25	5.1
2.20	0.22	0.19	0.46	0.13	—	0.20	4.1
2.76	0.16	0.33	0.45	0.18	0.11	0.55	9.6
2.07	0.32	0.20	0.44	0.16	—	0.23	4.9
1.89	0.15	0.11	0.47	0.11	0.11	0.39	2.7
2.46	0.25	0.24	0.75	0.30	0.13	0.58	7.5
GM 2.12	0.19	0.16	0.43	0.15		0.30	5.04
CL 1.78-2.52	0.12-0.28	0.10-0.25	0.33-0.55	0.11-0.21		0.23-0.41	3.96-6.41
Range 1.31-2.92	ND-0.55	ND-0.36	0.18-0.75	ND-0.30	ND-0.13	0.14-0.58	2.79-9.6

NOTE: ND or — = no residue detected.
GM = geometric mean.
CL = 95 percent confidence limits.
[1]*Cis*-chlordane and/or *trans*-nonachlor.

TABLE 8. *Residues of organochlorine pollutants in tissues of brown pelicans found dead*

Residues, μg/g fresh wet weight												
Sex	Age	Tissue	DDE	TDE	DDT	Dieldrin	Heptachlor Epoxide	Mirex	Oxy-chlordane	*Cis*-chlordane[1]	*Cis*-nonachlor	Toxaphene	PCB's
South Carolina													
						1971							
M	12 wk	Carcass	0.47	0.19	0.10	0.10	0.10	—	—				4.0
		Brain	0.10	0.10	—	0.10	—	—					0.6
F	6 wk	Carcass	0.10	0.10	0.10	0.10	0.10	0.10	—				
		Brain	0.10	—	—	—	—	—					—
						1973							
F	8 wk	Carcass	0.48	0.14	0.11	0.13	—	—	—	—	—	—	0.7
		Brain	—	—	—	—	—	—	—	—	—	—	—
Georgia													
						1972							
F	AD	Carcass	5.50	0.78	—	5.30	0.16	0.73	0.15	0.43	0.45		10.0
		Brain	2.90	0.17	0.23	4.40	0.16	0.25	—	0.32	0.23		4.7
Florida													
						1972 (Atlantic Coast near Stuart)							
M	IM	Carcass	8.10	2.00	0.80	1.20	—	—	—	—	—		5.0
		Brain	2.70	0.39	0.33	0.82	—	—	—	—	—		3.2
M	IM	Carcass	5.80	1.30	0.46	0.90	—	0.23	—	0.10			5.0
		Brain	2.36	0.32	0.22	0.59	0.13	—	—	—			6.5
F	AD	Carcass	10.00	2.00	0.94	1.10	0.12	0.40	—	—			25.0
		Brain	0.36	—	—	—	—	—	—	—			0.5
M	IM	Carcass	6.70	1.64	0.55	0.97	0.20	0.28	—	—			15.0
		Brain	5.30	0.46	0.49	0.53	0.12	—	—	—			8.5
M	IM	Carcass	9.65	1.44	0.70	1.17	0.13	—	—	—			10.0
		Brain	4.00	0.75	0.38	0.96	—	0.12	—	—			9.4
						1973 (Florida Bay)							
M	IM	Carcass	1.38	—	—	0.21	—	0.12	—	0.26	—	—	0.9
		Brain	0.36	—	—	0.12	—	—	—	—	—	—	0.3
M	IM	Carcass	1.65	0.57	0.16	0.38	0.16	—	—	1.30	0.18	0.17	1.8
		Brain	0.10	—	—	—	—	—	—	—	—	—	0.3
M	AD	Carcass	0.91	—	—	0.15	—	—	—	—	—	—	1.5
		Brain	0.91	—	—	0.31	—	—	—	0.15	—	0.27	0.9
F	AD	Carcass	1.32	0.16	—	0.23	—	—	—	0.11	0.10	0.26	1.5
		Brain	0.32	—	—	—	—	—	—	—	—	—	0.5

NOTE: — = no residue detected.
A blank space indicates that either the sample was not analyzed for that chemical or the chemical was not quantified.
IM = fledged pelican that has not attained adult (AD) plumage.
[1] *Cis*-chlordane and/or *trans*-nonachlor.

Unlike the organochlorine residues, metal residues in pelican eggs from various parts of their geographic range showed little variation, but there were a few exceptions. Eggs from Louisiana contained 0.08 μg/g mercury (*9*), whereas eggs of Florida and South Carolina pelicans contained four to five times more (Table 10). Residues of arsenic were three times as high in eggs from South Carolina than in those from Florida. It is possible that differences in metal residues reflect local differences in contamination of pelican foods. There was no apparent difference in residues of 10 metals in livers of birds that were found dead compared with those that were shot. Indeed, differences in residues seemed more closely related to place of collection or age than to cause of death. Mercury residues varied more than residues of other metals; the highest residue was 56 times the lowest.

TABLE 9. *Probable causes of brown pelican mortality*

Sex	Age	State	Year	Probable Cause of Mortality
M	12 wk	SC	71	Overwhelming, acute bacteremia
F	5 wk	SC	71	Pneumonia
F	8 wk	SC	73	Open[1]
F	AD	GA	72	Myocardial necrosis and dieldrin poisoning
M	IM	FL	72[2]	Enteritis
M	IM	FL	72	Enteritis
F	AD	FL	72	Enteritis
M	IM	FL	72	Enteritis
M	IM	FL	72	Enteritis
M	IM	FL	73	Gunshot
F	IM	FL	73	Open
M	AD	FL	73	Combination of diseases including early air sacculitis, early aspergillosis, and valvular endocarditis
F	AD	FL	73	Fractured humerus: possible gunshot.

[1] No diagnosis could be made on the basis of necropsy.
[2] See text for further details.

Connors et al. (*13*) reported that mercury residues (wet weight) in livers of brown pelicans found dead ranged from 1.20 to 1.88 μg/g in California and from 5.14 to 17.36 μg/g in Florida. Residues in both eggs and livers of brown pelicans suggest that pelicans are exposed to less mercury in California or Louisiana than in either South Carolina or Florida.

DECLINE OF RESIDUES

Residues of *p,p'*-DDE, *p,p'*-TDE, *p,p'*-DDT, and dieldrin in brown pelican eggs significantly declined from 1969 through 1973 (Table 13). The rate of change in residues was different for each of the five organochlorines. There was a steep drop in TDE from year to year; the trend for DDT was somewhat erratic. Dieldrin residues dropped steeply until 1971 and then leveled off, whereas there was a significant decline of DDE from one year to the next except for a slight reversal in 1972. The PCB's reached a peak in 1972, then declined in 1973 to the lowest level in 5 years. There was a nine-fold decrease in TDE and 1.6- to 2.6-fold decreases in the other pollutants. Residue trends for certain other organochlorines are unavailable because either the residues of these compounds appear in pelican eggs infrequently, as with mirex and heptachlor epoxide, or the residue methodology needed to detect them was unavailable in 1971 or 1972, as with toxaphene, *cis*-chlordane and/or *trans*-nonachlor and *cis*-nonachlor.

TABLE 10. *Residues of heavy metals in brown pelican eggs*

Residues, μg/g fresh wet weight									
Cr	Ni	Se	As	Hg	Pb	Cd	Cu	Zn	Mg
South Carolina, 1971-72									
0.039	0.053	0.26	0.64	0.66	0.110	0.005	0.92	6.4	85
0.008	0.019	0.30	0.85	0.56	0.068	0.002	1.05	7.2	95
0.013	0.058	0.27	0.65	0.39	0.022	0.003	0.81	5.8	80
0.016	0.010	0.33	0.71	0.17	0.019	0.003	0.70	5.5	79
0.012	0.014	0.29	0.73	0.21	0.010	0.002	1.10	6.7	75
0.005	0.006	0.28	0.48	0.22	0.018	0.003	0.82	6.9	80
0.002	0.011	0.22	0.22	0.55	0.025	0.008	1.07	6.3	67
0.003	0.021	0.31	0.14	0.50	0.025	0.003	1.10	7.4	90
0.001	0.010	0.27	0.18	0.36	0.025	0.003	1.29	6.3	73
0.093	0.072	0.27	0.13	0.58	0.035	0.008	1.06	4.6	68
0.009	0.066	0.23	0.076	0.26	0.025	0.004	1.20	6.2	55
0.150	0.031	0.24	0.18	0.24	0.045	0.003	1.00	8.0	89
GM 0.011	0.022	0.27	0.31	0.36	0.029	0.004	1.00	6.4	77
CL 0.004-0.028	0.013-0.039	0.251-0.292	0.183-0.533	0.263-0.480	0.019-0.043	0.003-0.005	0.890-1.115	5.81-7.00	70.1-85.0
Range 0.001-0.15	0.010-0.072	0.22-0.33	0.076-0.85	0.17-0.66	0.010-0.11	0.002-0.008	0.70-1.29	5.5-8.0	55-95
Florida, 1969-70									
0.067	0.042	0.34	0.09	0.84	0.038	0.003	1.04	8.3	80
0.005	0.009	0.19	0.07	0.22	0.013	0.003	1.02	7.7	86
0.015	0.037	0.38	0.18	0.48	0.045	0.011	1.11	6.8	70
0.006	0.039	0.33	0.08	0.45	0.032	0.003	0.98	5.2	107
0.023	0.027	0.31	0.11	0.45	0.028	0.003	0.78	4.3	78
0.009	0.010	0.21	0.10	0.20	0.013	0.003	0.94	7.4	42
GM 0.014	0.023	0.28	0.10	0.39	0.025	0.004	0.97	6.4	74
CL 0.005-0.037	0.011-0.046	0.211-0.382	0.071-0.140	0.223-0.670	0.014-0.043	0.002-0.006	0.86-1.11	4.93-8.43	53.5-103.3
Range 0.005-0.067	0.009-0.042	0.19-0.38	0.07-0.18	0.20-0.84	0.013-0.045	0.003-0.011	0.78-1.11	4.3-8.3	42-107

[1] GM = geometric mean.
CL = confidence limits.

The decline in organochlorine residues in South Carolina can be attributed partly to local curtailment of these chemicals either for pest control or industrial uses. However, residue trends reflected by the migratory pelican and the migratory Atlantic menhaden (*Brevoortia tyrannus*), their chief prey fish, are influenced by conditions existing over a wide area. Most pelicans nesting in South Carolina winter farther south; about 10 percent winter in South Carolina, about 20 percent in Cuba or more southerly areas, and the remainder in Florida, almost exclusively on the Atlantic Coast (*28*).

Seven pools of regurgitated menhaden were collected in 1973; organochlorine residues were low (Table 14). Most DDT in menhaden is metabolized to DDE in the body of the pelican. The biomagnification of DDE from fish to

TABLE 11. *Residues of heavy metals in livers of brown pelicans*

Sex	Age[1]	State[2]	Year	Residues, µg/g fresh wet weight									
				Cr	Ni	Se	As	Hg	Pb	Cd	Cu	Zn	Mg
Found Dead													
F	8 wk	SC	73	0.026	0.078	1.01	1.02	0.12	0.27	0.01	4.7	26	137
M	IM	FL	73	0.049	0.053	4.04	0.54	6.20	0.21	0.23	9.0	50	183
F	AD	GA	72	0.020	0.016	1.71	0.23	0.33	0.10	0.03	8.3	33	165
F	AD	FL	72	0.070	0.019	2.80	0.47	6.30	0.10	0.73	5.4	41	205
Shot													
F	AD	FL	70	0.110	0.038	3.38	0.63	4.10	0.10	1.06	6.7	55	222
M	IM	FL	70	0.065	0.048	4.42	0.89	1.70	0.10	0.21	7.5	32	226
F	6 wk	SC	70	0.030	0.045	1.16	0.36	0.21	0.10	0.01	4.3	31	198
M	AD	SC	70	0.056	0.039	4.28	0.29	1.10	0.10	0.02	6.5	38	199

[1] IM = fledged birds that have not attained full adult (AD) plumage.
[2] SC = South Carolina, FL = Florida, GA = Georgia.

TABLE 12. *Correlation matrix for residues of five organochlorines and ten heavy metals identified in 18 eggs of the brown pelican*

	Simple Correlation Coefficient (r)													
	TDE	DDT	Dieldrin	PCB's	Cr	Ni	Se	As	Hg	Pb	Cd	Cu	Zn	Mg
DDE	0.464	0.468*	0.744**	0.699**	−0.288	−0.522*	−0.417	0.351	−0.453	−0.492*	−0.269	0.055	0.379	−0.255
TDE		0.564*	0.612**	0.439	−0.103	−0.374	−0.650**	−0.320	−0.466	−0.689**	−0.146	0.095	0.199	−0.484*
DDT			0.444	0.185	−0.39	−0.627**	−0.276	−0.52	−0.179	−0.461	0.009	−0.095	0.175	−0.283
Dieldrin				0.741**	−0.238	−0.486*	−0.636**	0.282	−0.617**	−0.501*	−0.111	−0.107	0.016	−0.482*
PCB's					−0.029	−0.262	−0.585*	0.303	−0.271	−0.197	0.123	0.121	0.193	−0.343
Cr						0.590**	0.165	0.008	0.160	0.397	0.125	−0.268	−0.065	0.060
Ni							0.247	−0.173	0.551*	0.563*	0.332	0.134	−0.298	0.089
Se								0.221	0.373	0.322	0.047	−0.153	−0.225	0.414
As									−0.100	0.146	−0.069	−0.363	0.001	0.241
Hg										0.701**	0.351	0.257	−0.117	0.292
Pb											0.318	0.094	−0.031	0.376
Cd												0.160	−0.254	−0.281
Cu													0.345	−0.147
Zn														−0.013

NOTE: **P < 0.05; *P < 0.01.

TABLE 13. *General decline in residues of organochlorine pollutants in eggs of the brown pelican*

Year	Sample Size	Residues, µg/g fresh wet weight				
		DDE	TDE	DDT	Dieldrin	PCB's
1969	15	5.45 A[2] (4.44-6.70)	1.65 A (1.30-2.10)	0.22 A (0.09-0.54)	1.16 A (1.03-1.52)	6.11 ABC (5.00-7.45)
1970	13	3.58 B (2.23-5.72)	0.79 B (0.53-1.20)	0.29 B (0.38-0.69)	0.82 A (0.52-1.32)	5.25 ABC (3.91-7.04)
1971	65	2.48 C (2.27-2.71)	0.48 C (0.43-0.53)	0.13 A (0.11-0.17)	0.46 B (0.40-0.52)	6.49 AB (5.44-7.73)
1972	72	3.03 B (2.70-3.40)	0.36 D (0.31-0.42)	0.15 A (0.13-0.18)	0.45 B (0.39-0.52)	7.51 A (6.68-8.46)
1973	104	2.09 D (1.91-2.29)	0.19 E (0.17-0.22)	0.17 A (0.15-0.20)	0.45 B (0.41-0.50)	4.75 C (4.26-5.31)

[1] Geometric mean with 95 percent confidence limits in parentheses.
[2] A significant difference (P < 0.05) among means for each chemical is indicated for those means not sharing a common letter. Means were separated using Duncan's New Multiple Range Test (*33*) with Kramer's Extension for Unequal Replication (Vogt 1971-73).

pelican eggs is 31 times, only 5 times for both DDT and TDE, and 18 times for DDT and metabolites (DDTR). The biomagnification from fish to pelican eggs is 29 times for PCB's and 23 times for total organochlorines (Figure 1). The migratory habits of the Atlantic menhaden (*15,27*) and the brown pelican confound the significance of biomagnification noted in this study. Residues of DDTR in South Carolina menhaden averaged 0.295 μg/g in the late 1960's (Philip A. Butler, U.S. Environmental Protection Agency, Gulf Breeze, Fla., 1974: personal communication); residues in menhaden have apparently declined over 50 percent from the late 1960's to 1973.

Declining residues of certain organochlorine pesticides and their metabolites were noted in the United States and several other countries over the last few years; the authors have a list of more than 50 literature references concerning residue declines in human food, wild birds, fish, invertebrates, water, soils, and agricultural products.

Johnston (*22,23*) documented the decline of DDTR in passerine birds in Florida and cited several references concerning the decline of organochlorine pesticides and their metabolites in other areas. Butler (*12*) had previously shown a drastic decline in DDTR in oysters (*Crassostrea virginica*) in South Carolina and other States in the 1960's. Investigations have shown both increases and decreases in residues of PCB's in birds in the early 1970's. The only major change involved a significant increase of PCB's in eggs of the osprey (*Pandion haliaetus*) that were collected in Maryland from 1969 through 1973 (*11*).

REPRODUCTIVE SUCCESS AND POPULATION LEVEL

The reproduction record of pelicans in South Carolina was excellent in 1973; 1.66 young were fledged per nest and a total of 2,726 young were fledged in the State (Table 15). From 1969 through 1972, the average number of young fledged per nest ranged from 0.69 to 0.92. For a number of years before 1969, Beckett (*3*) estimated that reproductivity was subnormal. According to Henny (*18*), an average of 1.2 to 1.5 young must be fledged by each breeding female each year in order to maintain a stable population. Thus reproductivity in South Carolina brown pelicans has been subnormal for a number of years, and the population has been declining (*3*). The improvement in

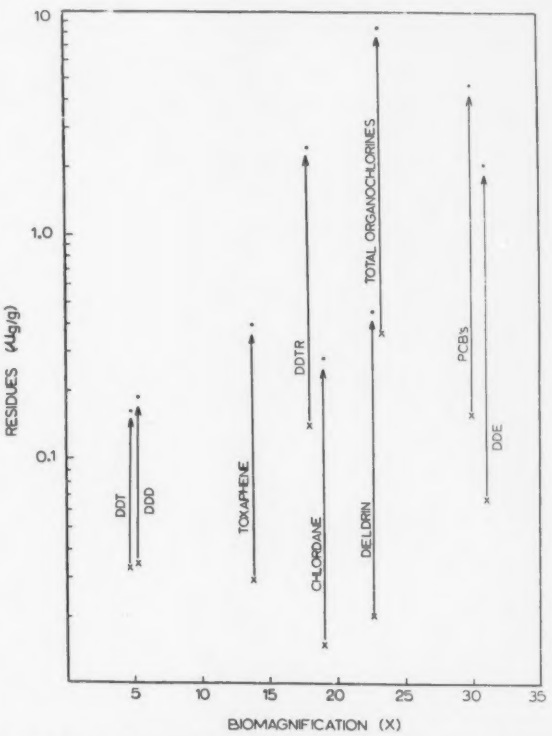

FIGURE 1. *Biomagnification of organochlorine residues from fish (X) to brown pelican eggs (O)*

TABLE 14. *Residues of organochlorine pollutants in Atlantic menhaden regurgitated by brown pelicans, South Carolina—1973*

RESIDUES, μG/G FRESH WET WEIGHT							
DDE	TDE	DDT	DIELDRIN	OXYCHLORDANE	*Cis*-CHLORDANE[1]	TOXAPHENE	PCB'S
0.04	0.04	0.04	0.03	0.01	—	0.03	0.08
0.06	0.04	0.05	0.03	0.01	0.01	0.04	0.17
0.07	0.02	0.03	0.02	—	—	0.02	0.25
0.06	0.03	0.03	—	—	0.01	0.04	0.14
0.05	0.03	0.02	0.02	—	0.01	0.02	0.10
0.08	0.03	0.02	0.02	—	0.01	0.02	0.25
0.15	0.07	0.06	0.04	—	0.02	0.04	0.24
GM 0.067	0.035	0.033	0.020			0.029	0.161
CL 0.045-0.099	0.024-0.050	0.022-0.049	0.011-0.038			0.021-0.039	0.105-0.248
Range 0.04-0.15	0.02-0.07	0.02-0.06	ND-0.04	ND-0.01	ND-0.02	0.02-0.04	0.08-0.25

NOTE: ND or — = no residue detected.
GM = geometric mean.
CL = 95 percent confidence limits.
[1] *Cis*-chlordane and/or *trans*-nonachlor.

TABLE 15. *Reproductive success of brown pelicans in South Carolina*

Year	Colony	Number of Nests	Number of Young Fledged	Young Fledged per Nest
1969	Cape Romain	1016	900	0.82
	Deveaux Bank	*250*	*80*	*0.32*
	Both colonies	1266	980	0.78
1970	Cape Romain	637	500	0.78
	Deveaux Bank	*479*	*445*	*0.93*
	Both colonies	1116	945	0.85
1971	Cape Romain	1094	949	0.87
	Deveaux Bank	*375*	*400*	*1.07*
	Both colonies	1469	1349	0.92
1972	Cape Romain	763	514	0.67
	Deveaux Bank	*652*	*456*	*0.70*
	Both colonies	1415	970	0.69
1973	Cape Romain	836	1082	1.29
	Deveaux Bank	*810*	*1644*	*2.03*
	Both colonies	1646	2726	1.66

reproduction in 1973 was probably related to a decline in residues inasmuch as authors previously found strong correlative evidence that DDE inhibited reproductivity in the brown pelican (*10*). In addition, excellent conditions of tides, weather, and food supply favored the successful reproductive effort.

Conclusion

Residues of organochlorines in brown pelican eggs decreased from 1969 through 1973. In 1973, the first time in many years, pelicans reproduced well. The improved reproductivity seemed related to the decline in organochlorine residues and favorable conditions of tides, weather, and food supply.

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BRIEF

Blood Levels of Chlorinated Hydrocarbon Residues in the Population of a Continental Town in Croatia (Yugoslavia)[1]

Elsa Reiner, Blanka Krauthacker, Marinko Stipcevic, and Zlata Stefanac

ABSTRACT

Plasma or serum samples of 147 individuals from the general population of a continental town in Croatia (Yugoslavia) were analyzed for chlorinated hydrocarbons in 1975. The compounds were determined by gas chromatography and identified by comparing their retention times with those of known standards. All samples contained p,p'-DDE; mean concentration was 35.3 ppb. Only 20 samples contained p,p'-DDT; mean concentration was 22.7 ppb. Concentrations of α-BHC, lindane, and p,p'-TDE were 3.25, 4.09, and 11.6 ppb, respectively.

Introduction

No published data seem to be available on the blood content of chlorinated hydrocarbon residues in the population of Yugoslavia. The use of chlorinated hydrocarbons has recently been restricted in this nation, and it seemed reasonable for the authors to initiate a survey which should establish the present body burden of chlorinated hydrocarbon pesticides and provide the base for a followup study. A total of 147 individuals in a continental town in Croatia were selected, and their plasma or serum was analyzed for compounds listed in Table 1. Lindane and *p,p'*-DDT, which appear in Table 1, are recommended for use as active ingredients in formulations used for plant protection in Yugoslavia (*4*).

TABLE 1. *Concentrations of chlorinated hydrocarbons in 147 samples of human plasma or serum, Croatia (Yugoslavia)—1975*

Compound	Concentration, ppb	
	Mean ± SEM (n)[1,2]	Range
α-BHC	3.25± 0.50 (57)	0.11- 15
Lindane	4.09± 0.62 (23)	0.45- 15
p,p'-DDE	35.3 ± 1.5 (147)	8.4 -118
p,p'-TDE	11.6 ± 2.7 (7)	3.0 - 23
p,p'-DDT	22.7 ± 3.3 (20)	2.2 - 81

[1](n) = no. samples which contain compound.
[2]SEM = standard error of mean.

[1] Institute for Medical Research and Occupational Health, Yugoslav Academy of Sciences and Arts, 158 Mose Pijade, 41000 Zagreb, Yugoslavia. POB 02-291. Work supported in part by Grant PR 2-515-2, U.S. Environmental Protection Agency, Washington, D.C.

Sampling and Analysis

The presence of chlorinated hydrocarbons was determined by gas chromatography. Compounds were extracted within 24 hours after sampling according to the procedure of Dale et al. (*1*). From each individual, two 1.0-ml samples acidified with formic acid were extracted four times with 3 ml hexane. The combined extracts were purified on a florisil column containing 1 g florisil and approximately 1 g anhydrous Na_2SO_4. The hexane was evaporated from the eluates and the compounds were redissolved in 1.0 ml hexane.

Conditions and operating parameters for GC analysis were:

Instrument Varian 2800 gas chromatograph

Detector H^3-Sc electron-capture

Columns Glass, packed with

A. 1.95 percent QF-1
1.5 percent OV-17 on Gas-Chrom Q

B. 4 percent SE-30 and 6 percent DC-210 on Gas-Chrom Q 80/100 mesh

C. 3 percent QF-1 and 6 percent DC-200 on Varaport 30

The best separation was obtained on column B. On all columns, compounds were identified by comparing their retention times with those of known standards. Solutions of standards in hexane were treated in the same way as the hexane extracts. Although purification of extracts on a florisil column is not included in the procedure of Dale et al. (*1*), it was necessary in this study because fatty acids were found in the extract. It was shown, however, that no chlorinated hydrocarbons were lost by that procedure.

Results and Discussion

Samples of plasma (92) or serum (55) of 147 individuals were analyzed for the presence of chlorinated hydrocarbons. The test group included 65 males and 82 females; their mean age was 42

years, ranging from 8 to 92 years. Blood samples were obtained from clinical laboratories during 1975. To the authors' knowledge, none of the individuals had had previous occupational or accidental exposure to chlorinated hydrocarbons or pesticides in general. All samples contained *p,p'*-DDE, but *p,p'*-DDT was found in only 20 samples (Table 1). In five of the 20 samples the concentration of *p,p'*-DDT was higher than *p,p'*-DDE; in the other 15 samples the reverse was true. The mean ratio of *p,p'*-DDE to *p,p'*-DDT in these 20 samples was 2.3. Like *p,p'*-DDT, the other compounds were not found in all samples analyzed. The concentration range for a given compound is large and the concentrations correspond to data published for other populations (*2*,*3*).

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APPENDIX

Chemical Names of Compounds Discussed in This Issue

AROCLOR	A mixture of chlorinated terphenyls
AROCLOR 1260	PCB, approximately 60% chlorine
BHC (Benzene Hexachloride)	1,2,3,4,5,6-Hexachlorocyclohexane (mixture of isomers)
CHLORDANE	1,2,3,5,6,7,8,8-Octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene. The technical product is a mixture of several compounds including heptachlor, chlordene, and two isomeric forms of chlordane.
DDE	Dichlorodiphenyl dichloro-ethylene (degradation product of DDT) *p,p'*-DDE: 1,1-Dichloro-2,2-bis(*p*-chlorophenyl) ethylene *o,p'*-DDE: 1,1-Dichloro-2-(*o*-chlorophenyl)-2-(*p*-chlorophenyl)ethylene
DDT	Main component (*p,p'*-DDT): α-Bis(*p*-chlorophenyl) β,β,β-trichloroethane. Other isomers are possible and some are present in the commercial product. *o,p'*-DDT: [1,1,1-Trichloro-2-(*o*-chlorophenyl)-2-(*p*-chlorophenyl) ethane]
DIELDRIN	Not less than 85% of 1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-*endo-exo*-5,8-dimethanonaphthalene
HCB	Hexachlorobenezene
HEPTACHLOR EPOXIDE	1,4,5,6,7,8,8-Heptachloro 2,3-epoxy-3a,4,7,7a-tetrahydro-4,7-methanoindan
LINDANE	*Gamma* isomer of 1,2,3,4,5,6-hexachlorocyclohexane
MIREX	Dodecachlorooctahydro-1,3,4-metheno-1H-cyclobuta[cd]pentalene
NONACHLOR	1,2,3,4,5,6,7,8-Nonachlor-3a,4,7,7a-tetrahydro-4,7-methanoindan
PCB'S (Polychlorinated Biphenyls)	Mixtures of chlorinated biphenyl compounds having various percentages of chlorine
SELENIUM	Sodium selenate
TDE	2,2-Bis (p-chlorophenyl)-1,1-dichloroethane (including isomers and dehydrochlorination products)
TOXAPHENE	Chlorinated camphene (67-69% chlorine): product is a mixture of polychlor bicyclic terpens with chlorinated camphenes predominating.

ERRATA

PESTICIDES MONITORING JOURNAL, Volume 10, Number 2, pages 41-43. Authors of the article "Pesticide Residues in Urban Soils from 14 United States Cities, 1970" are H. S. C. Yang, G. B. Wiersma, H. Tai, and W. G. Mitchell.

PESTICIDES MONITORING JOURNAL, Volume 10, Number 4, page 168. The following table was omitted from the brief, "DDT Residues in Air in the Mississippi Delta, 1975."

TABLE 1. *Monthly atmospheric levels of ΣDDT in the Mississippi Delta, 1972-75*

	Residues, ng/m³			
	1972	1973	1974	1975
January	10.8	3.9	3.0	2.2
February	12.6	4.8	3.6	3.8
March	32.6	11.1	7.6	2.7
April	34.1	11.4	7.7	3.5
May	17.2	18.6	15.6	9.2
June	16.2	49.5	12.8	13.8
July	117.2	9.6	24.3	11.9
August	515.3	25.6	37.9	19.0
September	378.8	24.6	19.4	18.4
October	37.6	18.9	5.1	2.6
November	14.8	11.9	3.3	2.3
December	6.3	2.4	2.1	1.3
Arithmetic mean	99.5	16.0	11.9	7.6
Geometric mean	35.0	11.8	8.1	5.1

Information for Contributors

The *Pesticides Monitoring Journal* welcomes from all sources qualified data and interpretative information on pesticide monitoring. The publication is distributed principally to scientists, technicians, and administrators associated with pesticide monitoring, research, and other programs concerned with pesticides in the environment. Other subscribers work in agriculture, chemical manufacturing, food processing, medicine, public health, and conservation.

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